PROJECT FLAMBEAU...

An Investigation of Mass Fire (1964-1967)

Final Report - Volume II:

CATALOGUE OF PROJECT FLAMBEAU FIRES, 1964-1967

by

Thomas Y. Palmer

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Work Unit 2536-A
DASA EO 850-68

1969

PACIFIC SOUTHWEST
Forest and Range
Experiment Station

FOREST SERVICE
U.S.DEPARTMENT OF AGRICULTURE
P.O. BOX 245, BERKELEY, CALIFORNIA 94701

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SUMMARY

This report summarizes, in catalogue form, the data available from nine experimental fires conducted by Project Flambeau from 1964 to 1967. The fires were burned as part of an investigation of mass fires sponsored by the Office of Civil Defense, Department of the Army, and by the Defense Atomic Support Agency, Department of Defense, Washington, D. C.

Project Flambeau was a research activity of the Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture, Berkeley, California. It had headquarters at the Station's Forest Fire Laboratory, Riverside, California. Before July 1966, Project Flambeau was known as the Fire Behavior Project of the Station.

The designations for the nine fires and the dates they were burned were:

Experimental Fire	Date
760-1-64	January 31, 1964
760-2-64	May 15, 1964
760-3-65	June 11, 1965
460-14-65	December 6, 1965
460-7-66	June 14, 1966
SR-3-67	June 8, 1967
SR-5-67	August 10, 1967
760-12A1-67	August 29, 1967
760-12-67	September 29, 1967

For each fire, this report provides information on (a) test data, (b) project number, (c) project officer, (d) types of measurements, (e) photography, (f) security clearance, (g) volume of records, (h) date of release, and (i) cooperative studies.

The following types of data were measured, recorded, and are available: fuel weight loss, flame temperature, air flow, differential and barometric pressures, fuel moisture, relative humidity, heat flux, gas temperature, soil temperature, snow melt measurements, thermal radiation, heat output, convection column, and weighing platform moisture.

The data available are on tabulated sheets, film, computer listings, slides, or strip charts. They are on file at the Forest Fire Laboratory, Pacific Southwest Forest and Range Experiment Station, P.O. Box 5007, Riverside, California 92507.

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For each of the nine experimental fires, this report provides information on (a) test data, (b) project number, (c) project officer, (d) types of measurements, (e) photography, (f) security clearance, (g) volume of records, (h) date of release, and (i) cooperative studies.

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Trade names and commercial enterprises or products are mentioned solely for necessary information. No endorsement by the U.S. Department of Agriculture or by the U.S. Department of Defense is implied.

CONTENTS

Experimental Fire 760-1-64

1. Test Data:

   a. Area covered: 5 acres.

   b. Ignited at: 1024 PDT, January 31, 1964.

   c. Location: southeast quarter of Township 2 North, Range 32 East, section 13, MDM, on U. S. Bureau of Land Management land, 8 miles northwest of Basalt, Mineral County, Nevada, about 50 miles north of Bishop, California.

   d. Elevation: 7,100 feet.

   e. Test Plots: nine piles of pinyon pine and Utah juniper, each 46.7 square feet and about 20 tons (dry weight); arranged in three rows 115 feet apart and from 5 to 7 feet tall.

2. Project Number: OCD-OS-62-173 and OCD-PS-64-3. Forest Service Line Project 2107.

3. Project Officer: Thomas Y. Palmer (formerly C. M. Countryman).

4. Types of Measurements:

   a. Flame Zone Temperatures:

      (1) Method: Chromel-alumel thermocouples were suspended above six piles (fig. 1). Ice-bath reference junctions were buried next to the piles. All signal lines were shielded.

      (2) Instrument Capabilities: Sixteen gauge thermocouple wire was used. Response time was about 30 seconds for 63 percent of a step input. Response time of the recorders used was 1 second for a full-scale excursion.

      (3) Data: A minimum of 4 minutes to a maximum of 90 minutes per sensor was recorded. Observations were recorded at 1 minute intervals. Processed data consist of tabulation sheets.

      (4) Volume of Data: 8 pages.

   b. Air Flow

      (1) Method: Anemometers were mounted in and around the fire area at 10 stations at the 2.5-, 5-, 10.5-, 22.5-, and 50-foot levels. Outside the fire, sensitive Thornthwaite anemometers were mounted on masts around the plot (fig. 2). Inside the fire, anemometers constructed at the Forest Fire Laboratory, Riverside, California were used. The signals consisted of a frequency proportional to

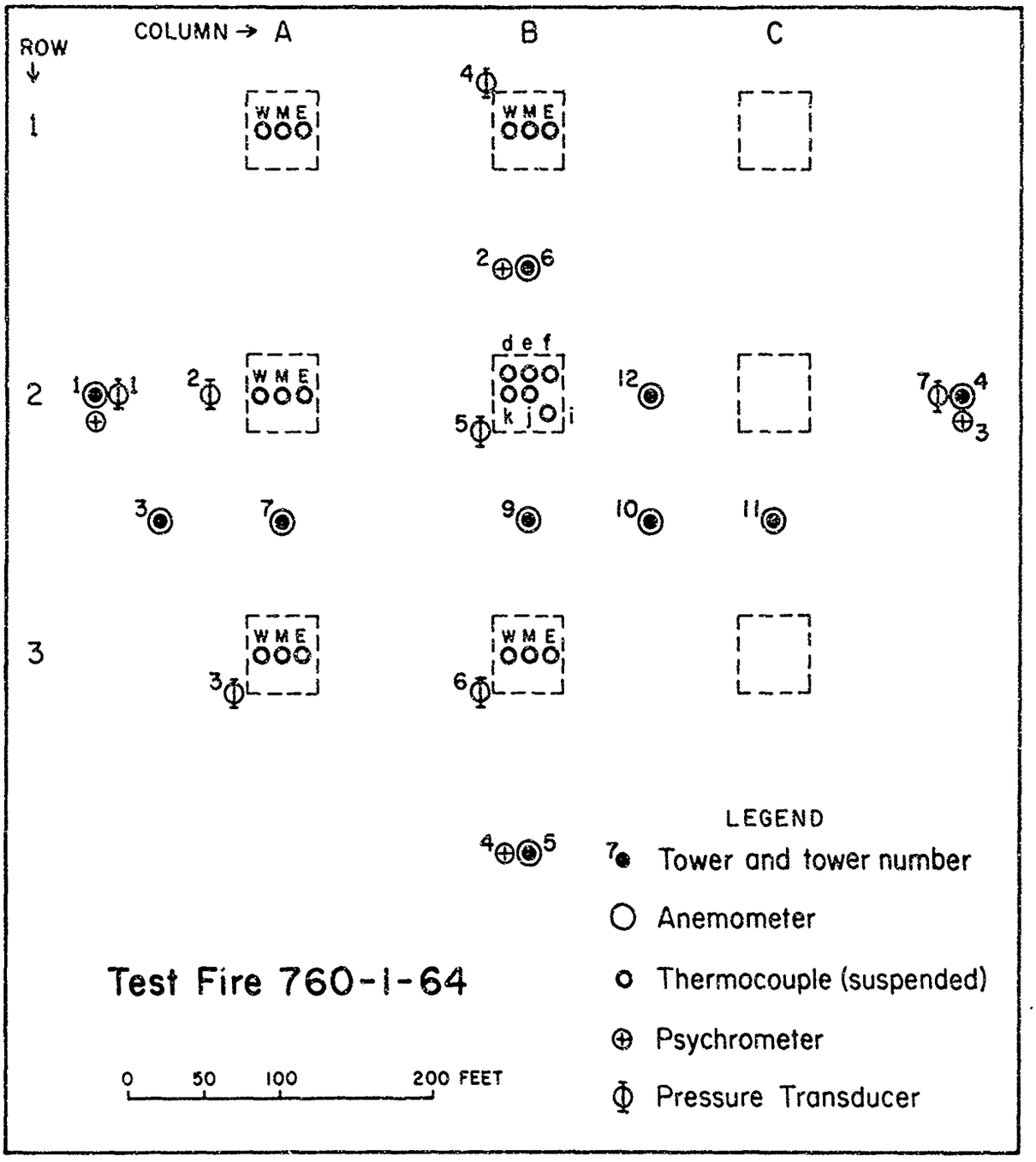


Figure 1.--*Plot layout for Experimental Fire 760-1-64, January 31, 1964. Thermocouples were set up at points W, M, E, d, e, f, j, k, and i.*

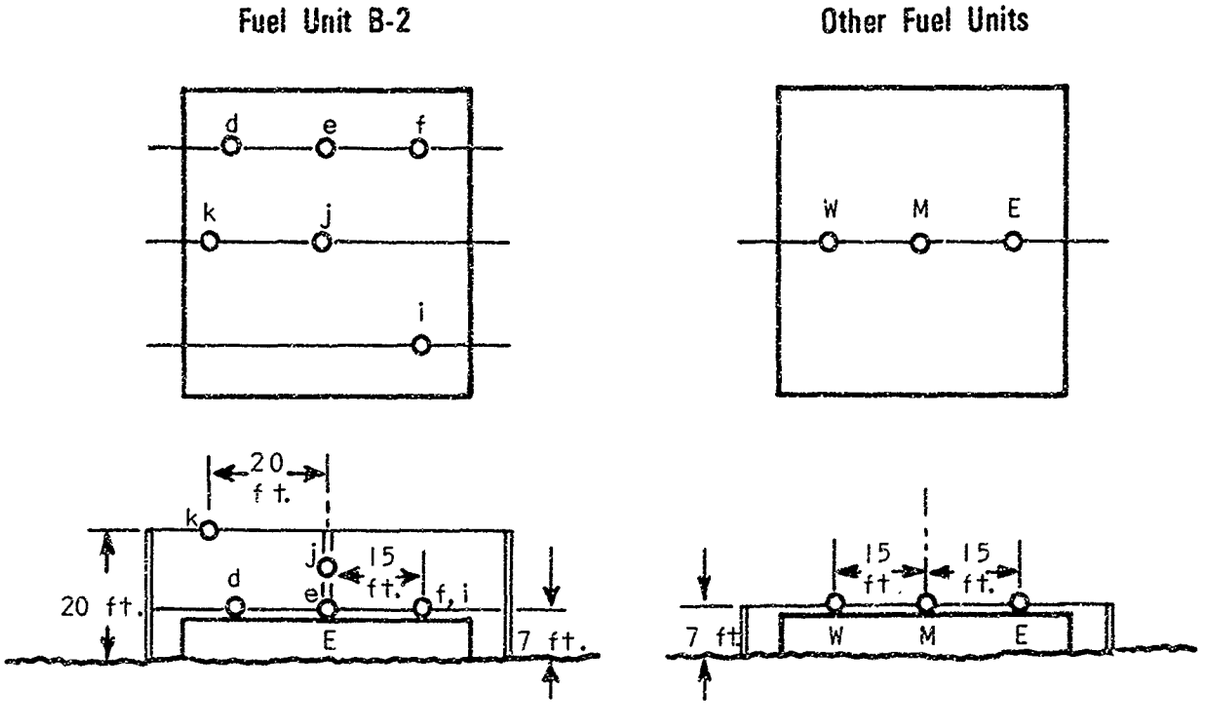


Figure 2.--*Locations of thermocouples for fuel piles in Experimental Fire 760-1-64, January 31, 1964, are shown by letters W, M, E, d, e, f, j, k, and i.*

wind speed. These signals were fed into an analog-to-digital converter. The wind direction transmitters were digital.

(2) Instrument Capabilities: The anemometers constructed at the Forest Fire Laboratory had a response time of about 3 seconds for 63 percent of a step change.[1] The response of the Thornthwaite anemometers is unknown, but is believed to be much faster than the other units.

(3) Data: Recorded onto punched paper tape. About 2 hours, or 3,200 observations, were recorded. Processed data consist of tabulation sheets.

(4) Volume of Data: 70 pages.

c. Pressure

(1) Method: Measured by an aneroid instrument (pressure transducer) with a potentiometer readout at seven stations in and around the fire area (fig. 1). The potentiometer was used as part of a bridge circuit so that the range could be expanded and set for the barometric pressure range encountered at the elevation of the plot. Individual units were calibrated at the Forest Fire Laboratory with an Ideal-

[1] Anemometer response is best described by a lag distance. These data are not available. See fig. 3 for approximate characteristics.

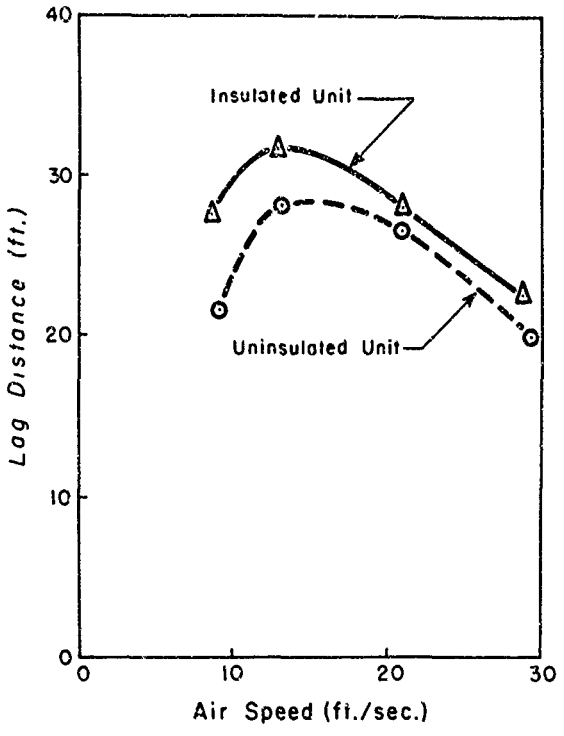


Figure 3.--*Differences in lag distance between insulated and uninsulated fire-resistant anemometers. The distance is the number of feet of air required to pass the instrument for it to reach 1/e or 63 percent of a step change in air velocity.*

Aerosmith Mercury Manometer. Units were dithered at 1-second intervals with a small direct-current motor on which an off-center flywheel was mounted.

(2) Instrument Capabilities: Units would respond to large changes in about one-half second. Small changes could be detected only after dithering. This dithering reduced the response time to about 1 second.

(3) Data: Recorded on strip charts for 1 hour and 33 minutes. Processed data consist of tabulation sheets.

(4) Volume of Data: 13 pages.

i. Fuel Moisture

(1) Method: An average of four samples of six sizes of fuel were collected before the burn. Moisture content was determined by xylene reflux distillation.

( ) Instrument Capabilities: Results are reproducible to within less than 1 percent. Absolute calibration methods have not been determined.

( ) Data: Results were recorded on tabulation sheets.

( ) Volume of Data: 1 page.

e. Relative Humidity:

(1) Method: Psychrometers were located in and around the fire area at four stations, 4-1/2 feet above ground (fig. 1). The wet and dry bulb psychrometers were constructed at the Forest Fire Laboratory and consisted of precision thermistor probes which were aspirated continuously. The thermistors were Fenwal Electronics type GS32P38. All thermistors were shielded against all sources of thermal radiation.

(2) Instrument Capabilities: Wet and dry bulb temperatures could be obtained to ± 1° F. with these units.

(3) Data: Recorded manually on tabulation sheets. About 115 observations were recorded in $2\frac{1}{2}$ hours.

(4) Volume of Data: 2 pages.

5. Photography:

a. Method: Photography by 16-mm cameras from four ground stations and documentation from an aircraft and from the ground, but no data are available as to the exact location of the cameras.

b. Instrument Capabilities: No data available as to the accuracy of the cameras used.

c. Data: Usable data were obtained. No clocks or time checks were recorded on the film.

d. Volume of Data:

Camera Station	Original	Copy
	ft.	
Documentary (Aerial)	100	100
Documentary (Ground)	- -	300
Camera Station (Ground)	- -	50
Camera Station (Ground)	600	100
Camera Station (Ground)	- -	300
Camera Station (Ground)	- -	100

6. Security Clearance: Unclassified.

7. Volume of Records: 94 pages of tabulated sheets and about 900 feet of film on file at the Forest Fire Laboratory, P. O. Box 5007, Riverside, California 92507.

8. Data Released: June 30, 1968.

9. Cooperators' Studies: Radiation, by University of California at Los Angeles. Winds Aloft, by Fire Meteorology Project, Pacific Southwest Forest and Range Experiment Station, Riverside, California.

Experimental Fire 760-2-64

1. Test Data:

   a. Area covered: 5 acres.

   b. Ignited at: 0830 PDT, May 15, 1964.

   c. Location: Township 2 North, Range 32 East, section 24, MDM, near Basalt, Mineral County, Nevada, about 70 miles north of Bishop, California.

   d. Elevation: 7,100 feet.

   e. Test Plots: 36 piles of pinyon pine and Utah juniper, each 46.7 square feet and about 20 tons (dry weight); arranged in rows 25 feet apart and from 7 to 10 feet tall (fig. 4).

2. Project Number: OCD-OS-62-173, OCD-PS-64-3. Forest Service Line Project 2107.

3. Project Officer: Thomas Y. Palmer (formerly C. M. Countryman)

4. Types of Measurements:

   a. Temperature (flame, gas, and soil):

      (1) Method: Aspirated chromel-alumel thermocouples were mounted on pipe towers (table 1), and linked by aspiration lines of 1-inch thinwall conduit to the air pump. Aspiration rates were 50-feet per second. Number 22 gauge thermocouple wire was used for the thermocouples. Bare chromel-alumel thermocouples were suspended over some piles by the small gauge (#22) wire. The wires were either burned out or destroyed by oxidation at the high temperatures. Other shielded thermocouples were also located in the aisles, but were not aspirated. Tethered balloons used to support temperature sensors in the convection column failed within 30 seconds because of high turbulence.

      Soil temperature was measured with insulated chromel-alumel 16 gauge thermocouples. Ice bath reference junctions were buried near the thermocouple location. Data were scanned into a strip chart recorder.

      (2) Instrument Capabilities: The aspirated thermocouples took approximately 4 seconds to respond to a 63 percent step change. Response times of the buried thermocouples were relatively slow, but this was no problem owing to the slow change of the soil temperature.

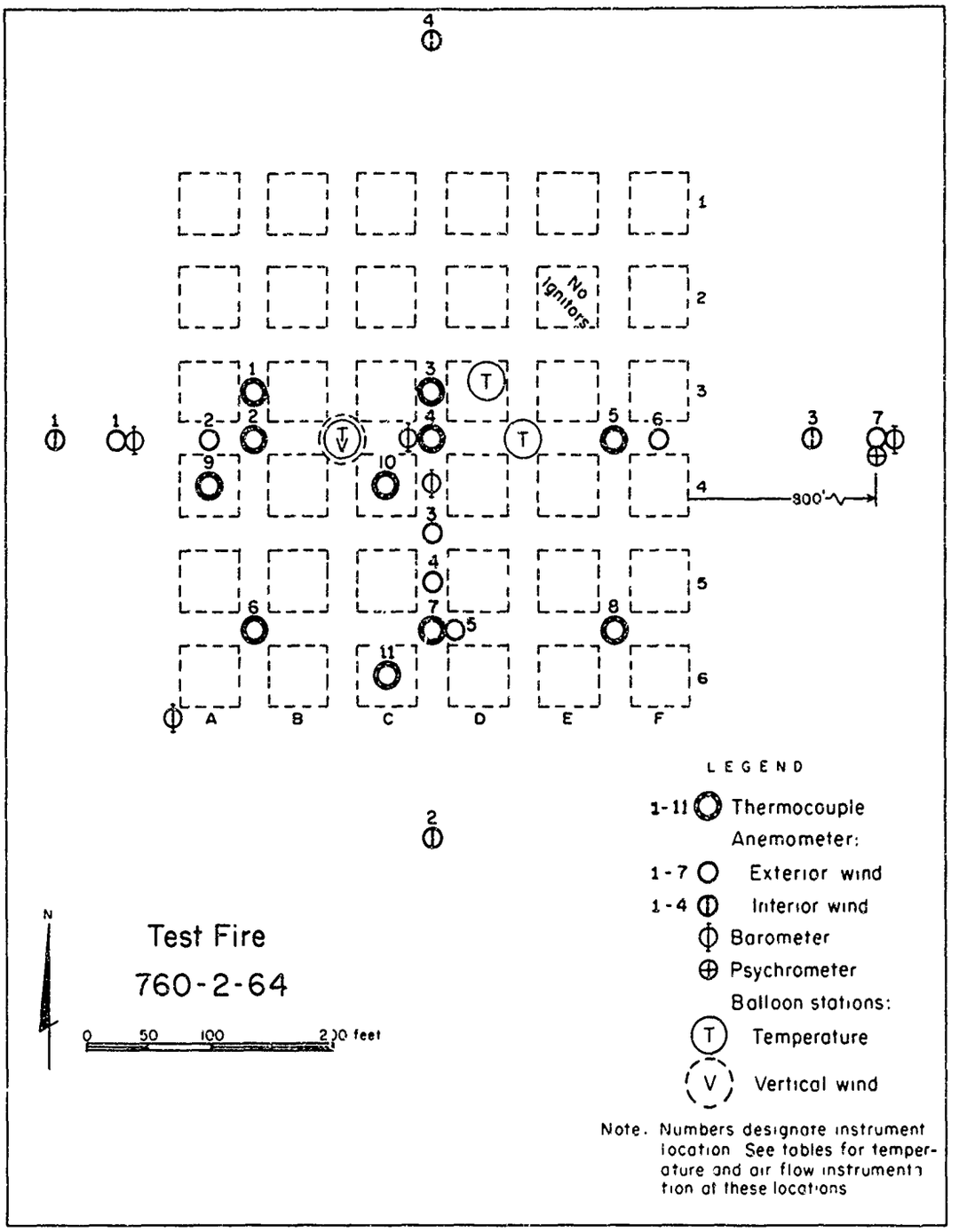


Figure 4.--*Plot layout for Experimental Fire 760-2-64, May 15, 1964.*

Table 1.-- Location and characteristics of thermocouples, Experimental Fire 760-2-64, May 15, 1964

Thermocouple number	Aspirated between piles (ft.)	Shielded between piles (ft.)	Bare in piles (ft.)	Bare in ground (in.)
		20-ft. Black Pipe Masts		
1, 2, & 3	7	--	--	--
	20	--	--	--
5, 6, 7, & 8	--	7	--	--
	--	20	--	--
9 & 11	--	--	7	--
	--	--	20	--
10	--	--	7	3
	--	--	20	6
		50-ft. Telescoping Mast		
4	7	--	--	3
	20	--	--	6
	50	--	--	--

(3) Data: Recorded on Varian strip charts and processed on tabulation sheets.

(4) Volume of Data: 12 pages.

b. Air Flow

(1) Method: Wind speed measurements were made with anomometers located on 11 towers at the 7-, 20-, and 50-foot levels in and around the fire area (table 2). Horizontal wind speed measurements were made with anemometers constructed at the Forest Fire Laboratory, Riverside, California. The devices provided a frequency signal to a frequency-to-voltage converter. The voltage output was then fed onto an analog-to-digital converter and then entered into punch tape. The wind direction transmitters were potentiometers with wind vanes attached. These signals were analog and were fed into analog-to-digital converters and then entered into punch tape. Vertical winds were measured with single-ended fan-type anemometers. The output of these devices was a frequency proportional to wind speed, with a second signal to indicate direction of rotation. These signals were processed with a zero center frequency-to-voltage converter and recorded on a zero center recording potentiometric recorder. All units within the fire area were wrapped with ceramic felt insulation to protect them against heat.

Table 2.--Locations of anemometers on towers, Experimental Fire 760-2-64, May 15, 1964

Anemometer number	Level of anemometer			
	White cup	Vertical	Westberg	Potentiometer wind vane
	Feet			
	50 FT. TRIANGULAR TOWER			
A 1	7	7	--	7
	20	20	--	20
	50	50	--	50
A 3	7	7	--	7
	20	20	--	20
	50	50	--	50
A 7	20	--	--	20
	50	--	--	50
	20 FT. TELESCOPING MASTS			
A 2,4,5, & 6	7	--	--	7
	20	--	--	20
I 1,2,3, & 4	--	--	7	7
	--	--	20	20

(2) Instrument Capabilities: The cup-type anemometers had a response time of about 3 seconds for 63 percent of a step change in air speed. The fan-type anemometers used for vertical air flow measurements had a response time of about 5 seconds for 63 percent of a step change in air speed.

(3) Data: Data from towers labeled 1,2,3, and 4 were recorded on a strip chart. Data from towers A 1 through 7 were recorded on punch tape and all data is processed on tabulation sheets.

(4) Volume of Data: 250 pages.

c. Pressure:

(1) Method: Pressure was measured in and around fire area at four stations by a bellows-type (pressure transducer) instrument with a potentiometer readout (fig. 4). The device was used as part of a bridge circuit so that the range could be expanded and set for the barometric pressure range encountered at the elevation of the plot. The individual units were calibrated at the Forest Fire Laboratory by . Ideal-Aerosmith Mercury Manometer. Units were dithered at 1-second intervals by a small direct current motor on which an off-center flywheel was mounted.

(2) Instrument Capabilities: Units would respond to large changes in pressure in about one-half second. Small changes could be detected only after dithering. This lag reduced the response time to about 1 second.

(3) Data: No significant variations were indicated on sensors. No data recorded.

d. Relative Humidity:

(1) Method: Wet and dry bulb psychrometer readings were made during the 4 days before the burn. A psychrometer was located 800 feet east of the fire area. It consisted of precision thermistor probes with a continuously operated aspiration. The thermistor was a Fenwal Electronic type GS32P38. The thermistor was shielded against all sources of thermal radiation. A regulated power supply was used with a precision bridge to obtain the signal data. All signal lines were shielded.

(2) Instrument Capabilities: Wet and dry bulb temperatures could be obtained to ± 1° F. with these units.

(3) Data: About 110 observations were made before the fire. None was made during the fire. Processed data consist of tabulation sheets.

(4) Volume of Data: 5 pages.

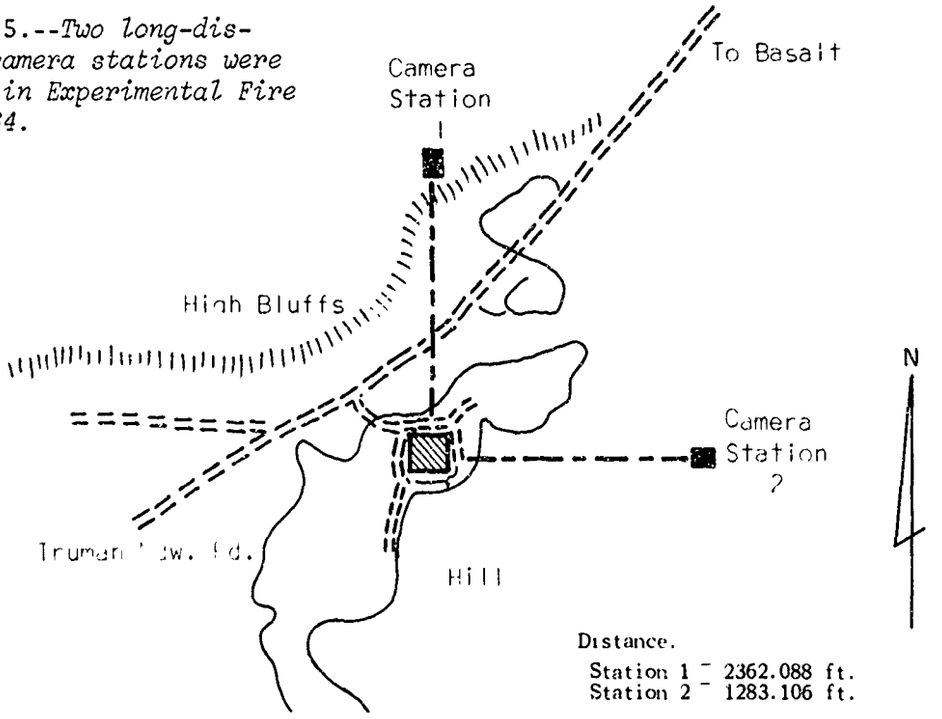


Figure 5.--*Two long-distance camera stations were set up in Experimental Fire 760-2-64.*

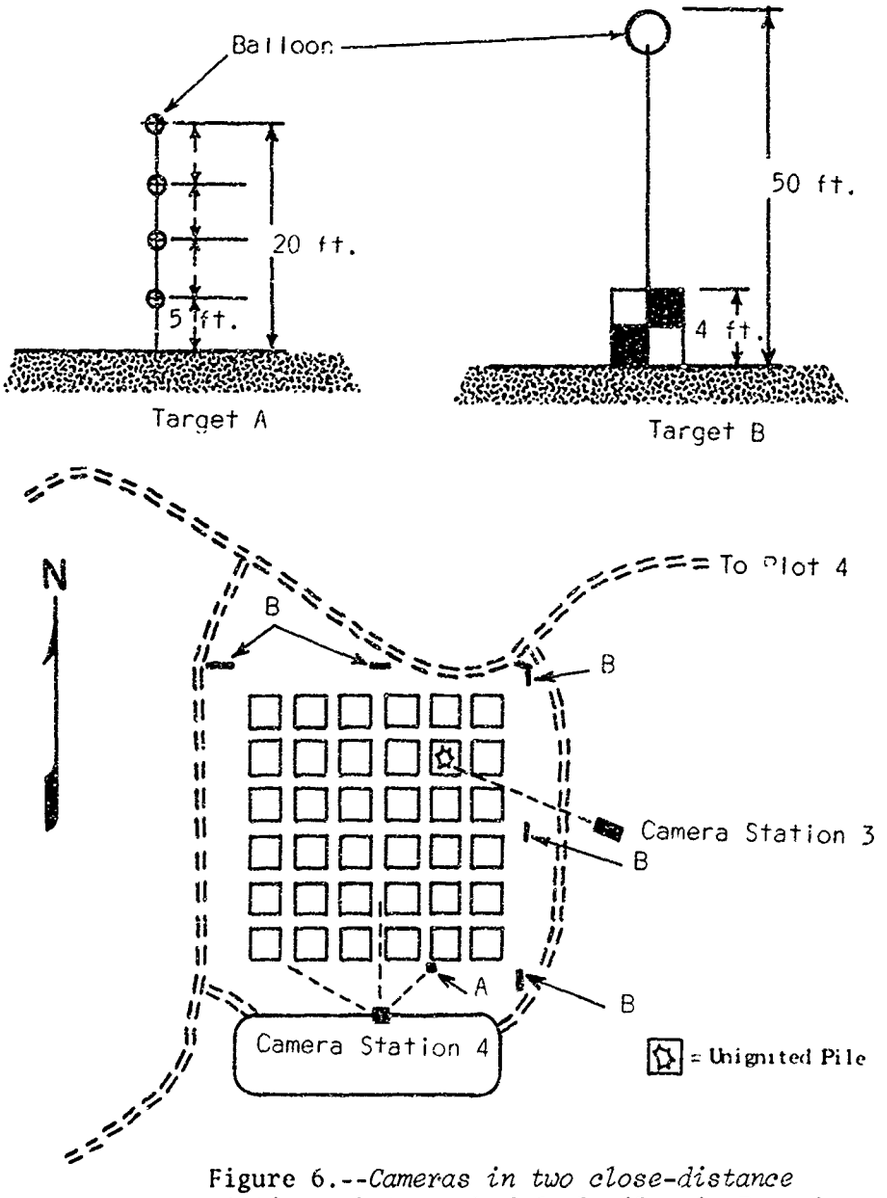


Figure 6.--*Cameras in two close-distance stations photographed fuel piles in Experimental Fire 760-2-64.*

5. Photography:

   a. Method:

      All cameras were 16 mm (figs. 5,6).

   b. Instrument Capabilities: No data are available on the accuracy of the cameras that were used.

   c. Data: Usable data were obtained from all cameras.

d. Volume of Data:

Camera Station	Camera Number	Frames per/sec.	Original (ft.)	Copy (ft.)
1	--	--	--	--
2	C-4	1	200	200
4	C-9	1	100	100
	C-6	1	75	75
	C-8	1	75	75
	C-7	200	200	200
Documentary	--	24	1200	750

6. Security Clearance: Unclassified

7. Volume of Records: 267 pages of tabulated sheets, and 1,900 feet of 16 mm film, on file at the Forest Fire Laboratory, P. O. Box 5007, Riverside, California 92507.

8. Data Released: June 30, 1968.

9. Cooperators' Studies: Radiation, by University of California, Los Angeles, California.

Experimental Fire 760-3-65

1. Test Data:

   a. Area covered: 5 acres.

   b. Ignited at: 0925 PDT, June 11, 1965.

   c. Location: northeast quarter of Township 2 North, Range 32 East, section 24, MDM, near Basalt, Mineral County, Nevada, about 50 miles north of Bishop, California.

   d. Elevation: 7,100 feet.

   e. Test Plots: nine piles of pinyon pine and Utah Juniper, each 46.7 square feet and about 20 tons (dry weight); arranged in three rows in each direction and from 5 to 7 feet tall.

2. Project Number: OCD-OS-62-173 and OCD-PS-64-3. Forest Service Line Project 2107.

3. Project Officer: Thomas Y. Palmer (formerly C. M. Countryman).

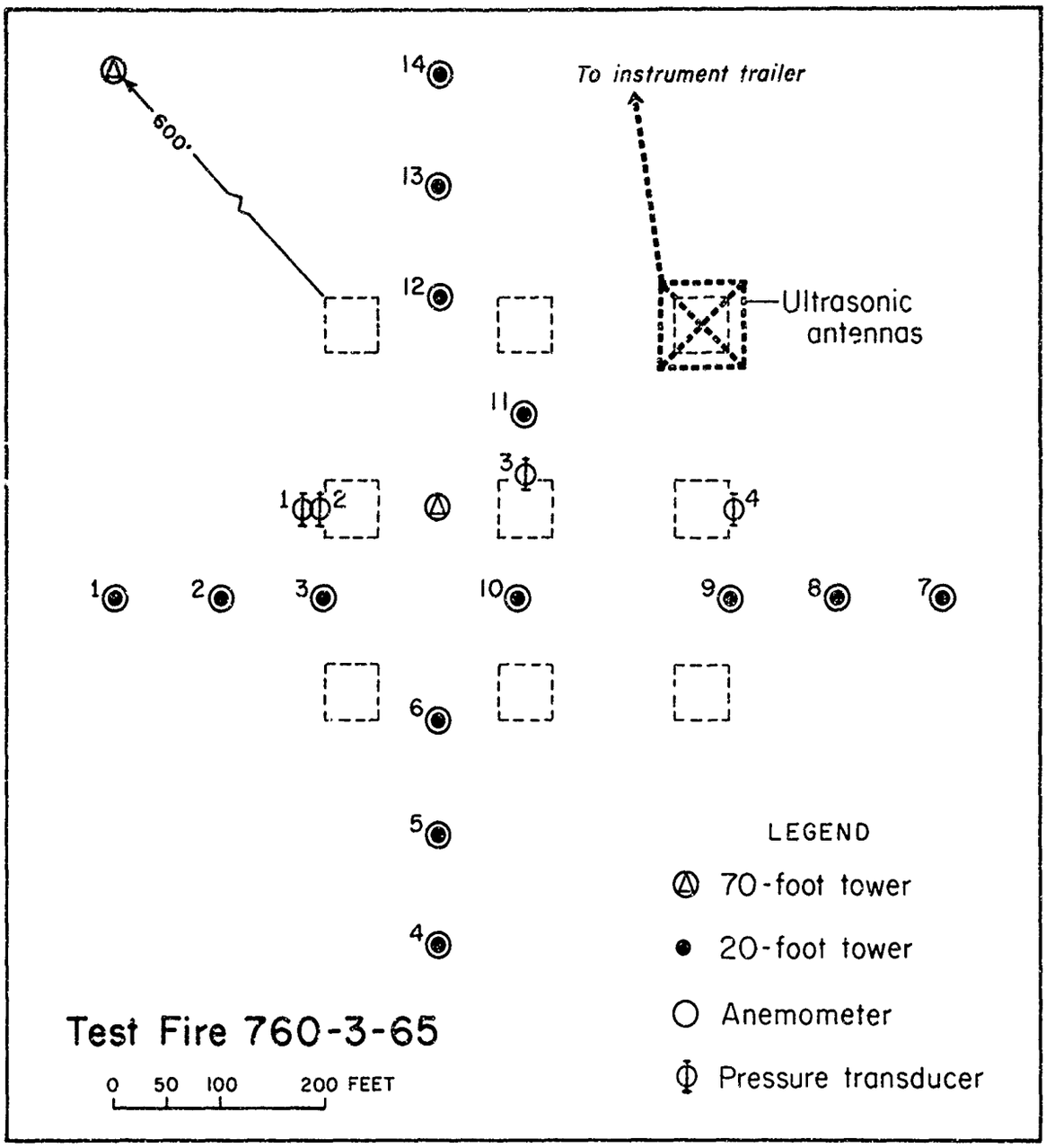


Figure 7.--*Plot layout for Experimental Fire 760-3-65, June 11, 1965.*

4. Types of Measurements:

a. Pressure:

(1) Method: Measured in and around the fire area at four stations by a bellows-type (pressure transducer) instrument with a potentiometer readout. The instrument was part of a bridge circuit used to expand the range and adjust the zero for the elevation encountered at the test area. Individual units were calibrated by an Ideal-Aerosmith Mercury Manometer at the Forest Fire Laboratory, Riverside, California. Units were dithered at 1-second intervals with a small direct current motor on which an off-center flywheel was mounted (fig. 7).

(2) Instrument Capabilities: Units would respond to large changes in pressure in about one-half second. Small changes could be detected only after dithering. This lag reduced the response to about 1 second.

(3) Data: No significant variations were indicated on sensors. No data were recorded.

b. Air Flow:

(1) Method: Second generation anemometers, built at the Forest Fire Laboratory, Riverside, California, were installed on towers in and around the fire area at 16 stations. Fourteen of the stations had sensors located at 7- and 20-foot levels. Two stations had sensors at the 7-, 20-, 50-, and 70-foot levels (fig. 7). The electronic recording system was the same as that used in Experimental Fire 760-2-64 except that vertical components were also punched into tape. Recording of wind direction was the same as that in the 760-2-64 Fire.

(2) Instrument Capabilities: The cup-type anemometers had a response time of about 3 seconds for 63 percent of a step change in air speed. The fan-type anemometers used for vertical air flow measurements had a response time of about 5 seconds for 63 percent of a step change in air speed.[2]

(3) Data: Recorded on punched paper tape, for about 75 minutes. Processed data consist of tabulation sheets.

(4) Volume of Data: 450 pages.

c. Noise Generation by Fire:

(1) Method: Electrical noise generated by the fire was observed on two separate antennas--one was hung across and the other

[2]Anemometer response is best described by a lag distance. These data are not available. See fig. 3 for approximate characteristics.

around the pile. The antennas consisted of stainless steel wire supported by ceramic insulators. Signals were observed by two oscilloscopes (fig. 7).

(2) Observations: The 60-cycle signal increased markedly when the flames touched the wire. Possibly ionization caused a ground loop. The 60-cycle originated in the generator powering the instrument trailer.

5. Photography: No usable data obtained.

6. Security Clearance: Unclassified.

7. Volume of Records: 450 pages of tabulated sheets, on file at the Forest Fire Laboratory, P.O. Box 5007, Riverside, California 92507.

8. Data Available for Release: June 30, 1968.

9. Cooperators' Studies: Radiation, gas analysis by University of California, Los Angeles.

Experimental Fire 460-14-65

1. Test Data:

   a. Area covered: 40 acres.

   b. Ignited at: 1215 PDT, December 6, 1965.

   c. Location: northeast quarter of Township 3 North, Range 29 East, Section 22, MDM, east of Mono Lake, Mono County, California, 30 miles due east of Lee Vining, California.

   d. Elevation: 7,250 feet.

   e. Test Plots: 324 piles of pinyon pine and Utah juniper, each 46.7 square feet, 18 by 18 feet, and about 20 tons (dry weight); arranged in rows 25 feet apart and from 5 to 7 feet tall(fig. 8).

2. Project Number: OCD-OS-62-173 and OCD-PS-64-3. Forest Service Line Project 2107.

3. Project Officer: Thomas Y. Palmer (formerly C. M. Countryman).

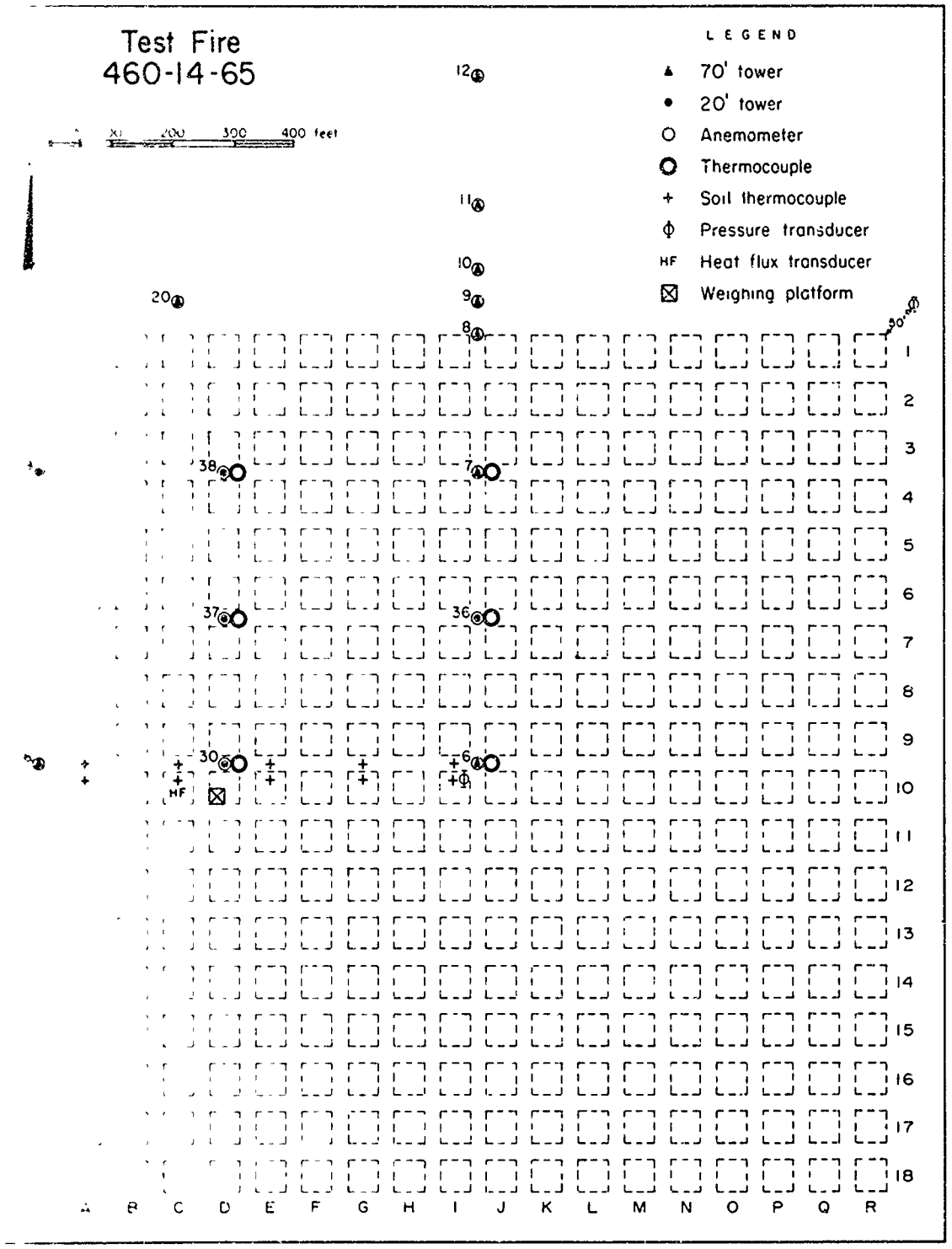


Figure 8.--*Plot layout for Experimental Fire 460-14-65, December 6, 1965.*

4. Types of Measurements:

a. Fuel Weight Loss:

(1) Method: A weight loss platform, 15 by 15 feet, was built into the southwest corner of pile D-10, and loaded with 7,000 pounds of fuel. The platform was constructed of angle iron, topped with a layer of scoria brick, and covered with sheet asbestos. Fuel was weighed by four load cells mounted on four concrete piers spaced on 9-foot centers under the platform. The bearing points of the load cells consisted of a hardened steel plate thermally insulated from, but rigidly fastened to, the platform framework. An 18-inch high, concrete block wall prevented burning fuel from rolling under the platform and damaging the load cells. Its top was nearly level with the top surface of the platform. The 1-inch clearance between the wall and the platform on four sides was closed by a strip of asbestos cloth (fig. 8).

(2) Instrument Capabilities: Load cell response time was almost instantaneous. The recorder system was the limiting factor. About 1 minute was required to scan all four load cells. The best resolution was about 6 pounds per load cell.

(3) Data: Readings from individual load cells were recorded at about 15-second intervals on a Brown multi-point recording potentiometer on strip charts. Processed data consists of 1 tabulation sheet.

(4) Volume of Data: 1 page.

b. Heat Flux:

(1) Method: Heat flux was measured by water-cooled heat flux transducers. Four sensors were placed 10 feet above the ground or 3 to 4 feet above the top of the fuel in pile C-10. Two sensors measured radiated energy only. A sapphire window (90^{o} view angle) was kept clean by a nitrogen purge. The other two instruments measured total energy (180^{o} view angle). A water tank and pump buried next to the pile supplied cooling water. A nitrogen tank was placed in the same enclosure. Signals were transmitted to the recording trailer over shielded wires (fig. 8).

(2) Instrument Capabilities: The heat flux transducers had a response time of about 0.15 second. The recorders had a full-scale response of 0.125 second. Full-scale output for the heat flux transducers was 60 $Btu/ft.^{2}/sec$.

(3) Data: Data from each sensor were recorded at 6-second intervals by Varian recording potentiometers onto strip charts. Processed data consist of tabulation sheets.

(4) Volume of Data: 2 pages.

c. Gas Temperature:

(1) Method: Gas temperatures were measured at six towers, four with sensors at 7- and 20-foot levels, and two with sensors at 3.5-, 7-, 13.5-, 20-, and 50-foot levels. The instruments were made up of stainless steel cans with an insulated blower motor enclosed. The blower motors were direct current, permanent magnet type. Filters were included in the cans. Motors were supplied by batteries buried at the base of the towers. Signal lines were well shielded (fig. 8).

(2) Instrument Capabilities: Response time for the aspirated thermocouple was tested at the Forest Fire Laboratory, Riverside, California, where it was found that 24-gauge chromel-alumel aspirated thermocouples at about 60 feet per second required 3.75 seconds to reach 63 percent of step decrease. The analog-to-digital converter required about 1 millisecond to make a conversion.

(3) Data: Data were recorded every 4 seconds in 8-level binary code on punched paper tape. Processed data consist of tabulation sheets.

(4) Volume of Data: 16 pages.

d. Soil Temperature:

(1) Method: Chromel-alumel thermocouples were used to measure soil temperatures at five piles: A-10, C-10, E-10, G-10, and I-10. Sensors were located 3 feet into the pile and 3 feet out of the pile at depths of 2, 4, 6, and 12 inches at each location. The thermocouples were insulated from soil moisture with a coating of epoxy resin. Ice bath reference junctions were buried next to the piles. Signals were transmitted to recording trailer over shielded wire, and scanned with a gold-plated step switch into a potentiometric recorder (fig. 8).

(2) Instrument Capabilities: Thermocouple gauge was AWG #24. Recorder response time was 1 second for full-scale deflection.

(3) Data: The soil temperature data were recorded on strip charts. Processed data consist of tabulation sheets.

(4) Volume of Data: 52 pages.

e. Air Flow:

(1) Method: Air speeds were measured at 46 stations on 14 towers (fig. 8). Each station consisted of three units: one sensing N-S, one E-W, and one vertical component. Each unit contains two reed switches closed by rotating magnets. Each

direction of rotation is determined by the sequence of reed switch closure and the speed of rotation by the frequency of closures. Reed switch performance is degraded by temperatures above 500°F., but is restored as the temperature drop. Hence, units exposed to high temperatures were insulated. All sensors were sampled for 2 seconds. At the end of this period, time was recorded on punched paper tape along with an identifier. The entire sequence required less than 10 seconds. The clock was set to record once every 10 seconds.

(2) Instrument Capabilities: Response of the bi-directional anemometers was tested in the wind tunnel at the Forest Fire Laboratory (fig. 8).

(3) Data: Air flow observations were made simultaneously at all stations. Sampling time was 2 seconds and recording time 8 seconds. Every 10 seconds, air flow was recorded on punched paper tape. Processed data consist of punch cards and computer machine listings.

(4) Volume of Data: 700 pages of computer listings.

f. Pressure:

(1) Method: Stainless steel vent pipes were connected by plastic tubing to manometers at the recording trailer (fig. 8). The slope-tube manometers had a range of ± 1 inch of water.

(2) Instrument Capabilities: Long, small diameter plastic tubes were used to connect the vent pipes to the manometers. The response times varied with the length of the tubing, from about 30 to 60 seconds.

(3) Data: The manometers were read manually at intermittent intervals and recorded on a tabulation sheet.

(4) Volume of Data: 1 page.

g. Fuel Moisture:

(1) Method: Fuel samples were taken before ignition, and moisture content was determined later at the Forest Fire Laboratory by the xylene reflux distillation method. Five sizes of fuel were sampled.

(2) Instrument Capabilities: Results are reproducible to within less than 1 percent. Absolute calibration methods have not been determined.

(3) Data: Measurements were recorded manually on a tabulation sheet.

(4) Volume of Data: 1 page.

h. Snow Melt Measurements:

(1) Method: Two snow depth courses were laid out 3 hours before ignition: one was between piles Q-4 and Q-5, and the other east of pile Q-5.

(2) Data: Readings from 12 stations consisting of snow depth, pre-burn, and post-burn were recorded manually on a tabulation sheet.

(3) Volume of Data: 1 page.

5. Photography:

a. Method: Two types of cameras were used: 16 mm and 35 mm. The only usable data obtained were 160 35-mm sequenced slides and 16-mm documentary film. The 35-mm camera was positioned north of the plot.

b. Instrument Capabilities: No data are available on the accuracy of the cameras.

c. Data: Usable data were obtained from the 35-mm camera. No clocks or time checks were recorded on the film.

d. Volume of Data: Original and one copy of slides. Original and one copy of 600 feet of 16-mm documentary film.

6. Security Clearance: Unclassified.

7. Volume of Records: 700 pages of computer listings, 74 pages of tabulated sheets, and about 600 feet of film on file at Forest Fire Laboratory, P.O. Box 5007, Riverside, California 92507.

8. Data Released: June 30, 1968.

9. Cooperators' Studies: Radiation and gas sampling, by University of California at Los Angeles. Synoptic Weather Pattern, atmospheric measurements and meso-scale analysis, by Fire Meteorology Project, Pacific Southwest Forest and Range Experiment Station, Riverside, California.

Experimental Fire 460-7-66

1. Test Data:

   a. Area covered: 30 acres.

   b. Ignited at: 0900 PDT, June 14, 1966.

   c. Location: southeast quarter of Township 3 North, Range 19 East, section 27, MDM, east of Mono Lake, Mono County, California, 30 miles due east of Lee Vining, California.

   d. Elevation: 7,200 feet.

   e. Test Plots: 240 piles of pinyon pine and Utah juniper, each 46.7 square feet, about 15 by 16 feet, and about 20 tons (dry weight); arranged in rows 25 feet apart and from 5 to 7 feet tall (fig. 9).

2. Project Number: DASA EO 850-67, OCD-OS-62-173, and OCD-PS-64-3. Forest Service Line Project 2107.

3. Project Officer: Thomas Y. Palmer (formerly E. M. Gaines).

4. Types of Measurements:

   a. Fuel Weight Loss:

      (1) Method: Fuel weight was measured on three 15- by 15-foot weight-loss platforms within the fire area, G-7, L-7, and O-7. Each platform was mounted on four Toledo precision load cells within about 3,000 pounds (tare weight plus fuel) on each load cell. Precision temperature-compensated power supplies were used to excite the 5,000 pound load cells. Teflon-to-teflon slip joints were used to relieve side loading effects caused by expansion and contraction of steel in the platforms. Shielded wire was used to transmit output data to the recording trailer (fig. 10). Direct current amplifiers were used to increase signal level. Gain was set at X2.5. Readings were recorded sequentially on a Brown 12-point recording potentiometer. Burning period time between readings for each load cell was 1.26 minutes. Each load cell was sensed 0.105 minute apart. Temperatures were recorded on the load cells and on the steel throughout the test burn (fig. 10).

      (2) Instrument Capabilities: Load cell response time was almost instantaneous. The recorder system limited the response due to a reading interval of 10 seconds. The load cells are linear to about .01 percent. The recorder is linear to about 0.25 percent. The best resolution was about 6 pounds per load cell. The major factor limiting accuracy was the 0.4-minute readout period per platform.

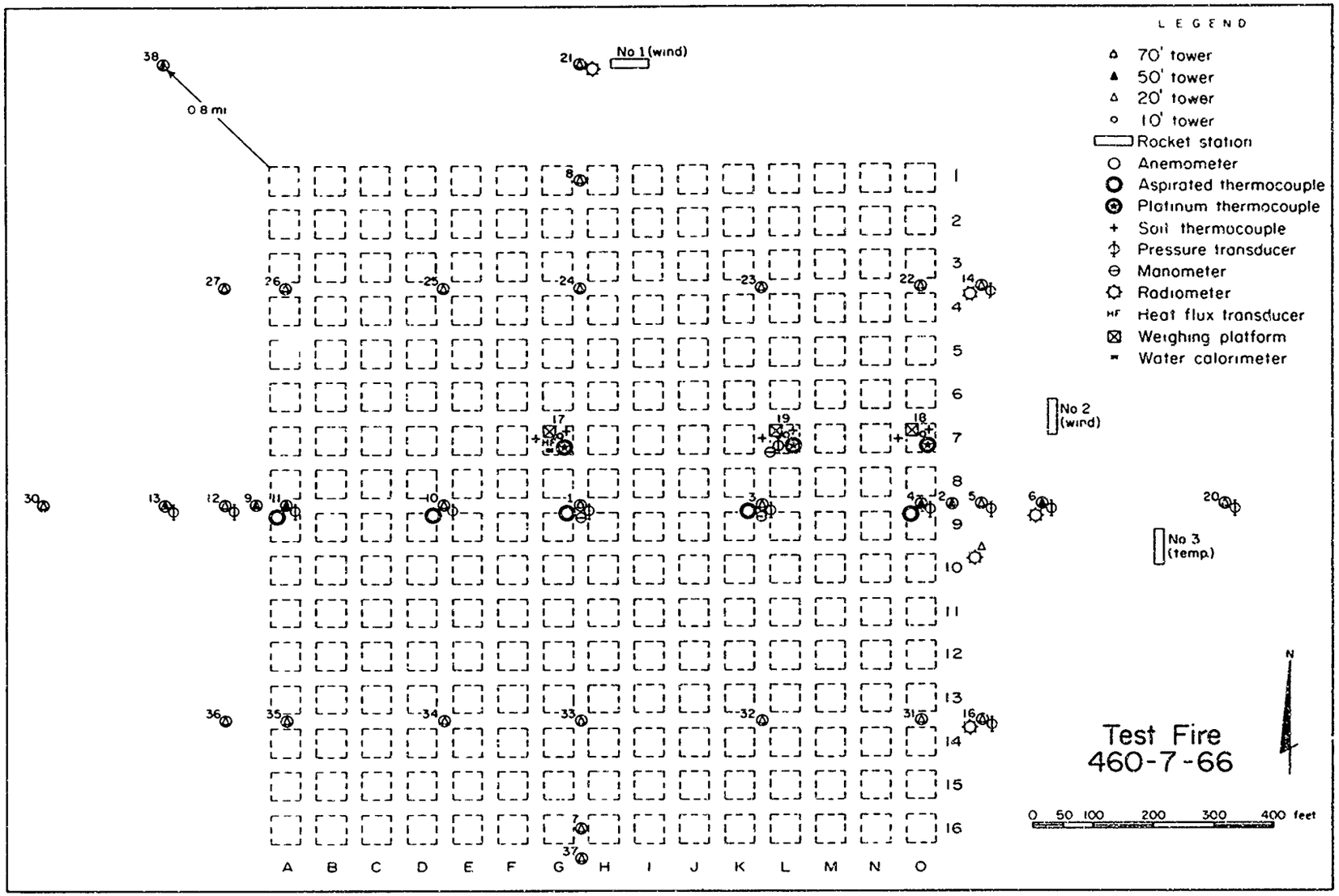


Figure 9.--*Plot layout for Experimental Fire 460-7-66, June 14, 1966.*

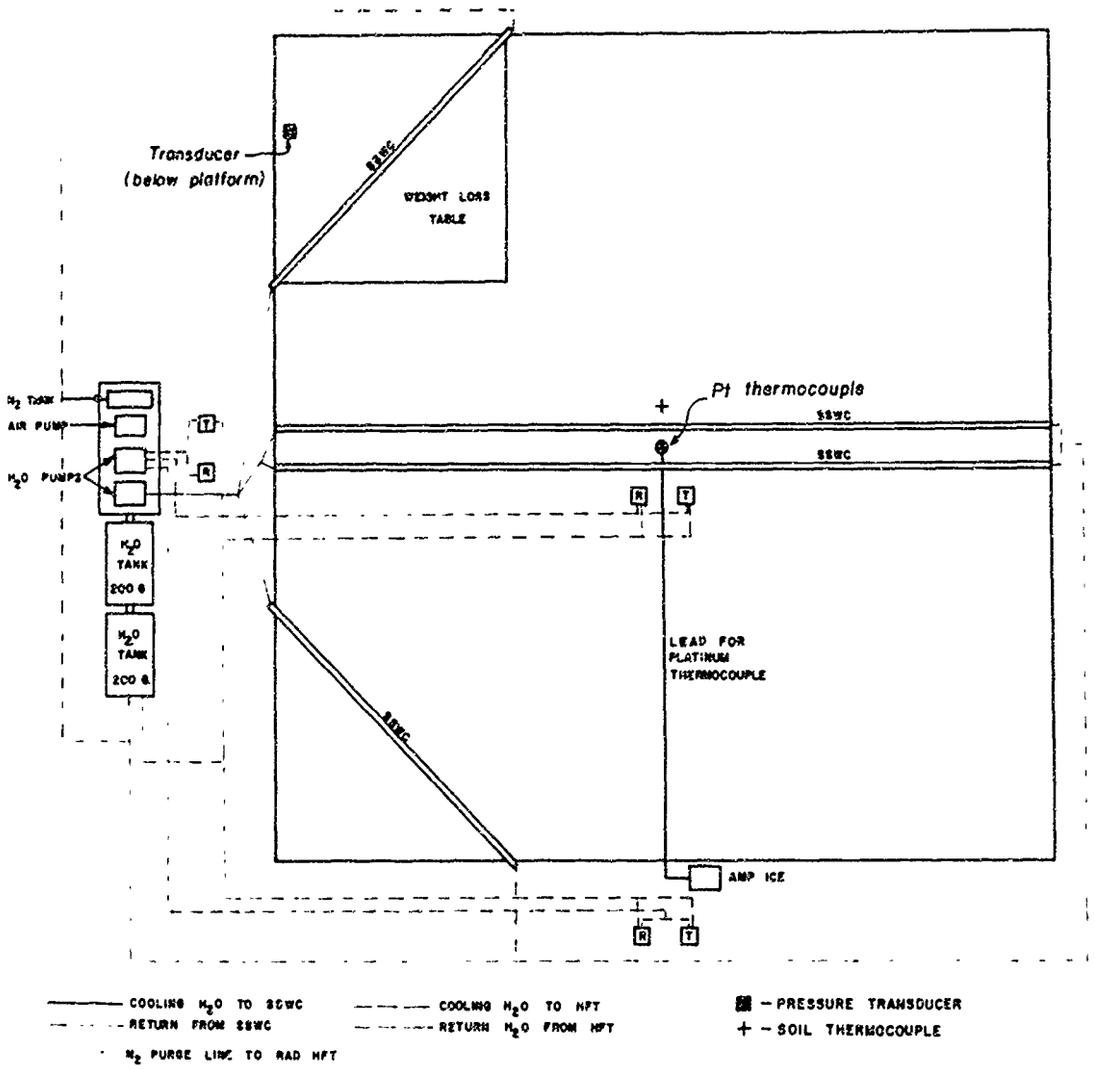


Figure 10.--*Instrumentation to measure fuel weight loss was set up in the center pile (6-7) of Experimental Fire 460-7-66.*

(3) Data: About 230 burning periods were recorded for each load cell. Some load cells indicate 7 to 15 burning-period sensing failures. Data were recorded on Brown recorders.

(4) Volume of Data: 25 pages of tabulation sheets.

b. Thermal Radiation:

(1) Method: Thermal radiation was measured on Beckman-Whitley flat plate radiometers at five locations outside the fire area (fig. 9). Four towers contained sensors at the 10-foot level, and one tower had sensors at the 10- and 45-foot levels. Data

were transmitted to the recording trailer over shielded wire, scanned with a gold-plated stepping switch, and recorded on a Varian Associates recording potentiometer. Plate temperature corrections were referenced to 0°C. with an ice bath thermocouple. All calibrations were checked before equipment was installed.

(2) Instrument Capabilities: The Beckman-Whitley flat plate radiometers used have a response time of about 0.2 minute for 63 percent of step increase. The maximum thermal radiation allowable is limited by the plate temperature rise. Plate temperature is limited to 240°F.

(3) Data: Observations were recorded at 10-second intervals. About 4,740 observations were recorded at the 45-foot level, about 1,225 observations at the 45-foot level. Plate temperature correction is available except for tower 14. The data were recorded on strip charts.

(4) Volume of Data: 350 pages of tabulation sheets.

c. Heat Flux:

(1) Method: Three sets of water-cooled heat-flux transducers were installed on pile G-7 to measure heat rate output (fig. 9). These units were set up in pairs--one to receive total energy and one to receive radiant energy. The unit receiving radiation had a sapphire window that was nitrogen-purged. One pair was mounted 10 feet high over the center of the pile facing down, one pair 4 feet high on the west side facing the pile, and one pair 4 feet high on the south side facing the pile. Cooling water from a 400-gallon tank buried in the aisle flowed through copper tubing to all units. The nitrogen supply was stored at the same location. All signals were amplified before being sent to the recording trailer.

(2) Instrument Capabilities: The heat flux transducers had a response time of about 0.15 second. The recorders had a full-scale response of 0.125 second. Full-scale output for the heat flux transducers was 60 Btu/ft.^{2}/sec.

(3) Data: Data signals were to have been recorded on strip charts, but no data were recorded because the wiring burned out.

d. Heat Output (Water Calorimeter Data):

(1) Method: Four continuous flow water calorimeters were installed over the center pile (G-7) (fig. 10). Water was pumped through copper pipes suspended across the pile. The inlet and outlet temperatures and water flow in each line were recorded. Two 50-foot pipes placed 6 inches apart were hung 10 feet above the ground running west to east across the pile. A 25-foot pipe was suspended diagonally across the weight loss platform, and

another 25-foot pipe was hung diagonally across the southwest corner. The copper pipe was 1/2-inch outside diameter with a .037-inch wall, and coated with a liver of sulfur solution. The 400-gallon water supply was buried along with the pump and flow measuring devices in the aisle just outside the pile. About 2.2 gallons of water per minute flowed through the 50-foot pipes, and 1.5 gallons per minute through the 25-foot pipes (fig. 10). Temperatures were measured by precision thermistors immersed in the water stream, one at each end of the copper tubing. Thermistor bridges were supplied with precision-constant current power supply. Signal data were transmitted to the recording station over shielded wire.

(2) Instrument Capabilities: The water-flow calorimeter was an experimental device designed for reason of economy to replace the weight loss platform. It could resolve a temperature difference (hot end over cold end) of $\frac{1}{2}^{o}$C.

(3) Data: Data were recorded on Varian Associates recording potentiometers. Readings were taken every 2 seconds and recorded on strip charts. About 1,755 observations from each pipe were recorded. Processed data consist of tabulation sheets giving the temperatures of the incoming and outgoing water and the differences between these two readings. All temperatures are recorded in degrees centigrade.

(4) Volume of Data: 150 pages.

e. Gas Temperature:

(1) Method: Gas temperatures were measured on five towers on an east-west transect through the center of the plot, as follows: two 20-foot towers with aspirated thermocouples at 7 and 20 feet; two 50-foot towers with aspirated thermocouples at 7, 20, and 50 feet; and one 50-foot tower with aspirated thermocouples at 3-1/2, 7, 20, and 50 feet were used. The instruments were constructed of stainless steel cans and driven by an insulated blower motor of direct current, permanent magnet type. The cans included filters. Motor power was supplied by batteries buried at the base of the towers. The thermocouple was chromel-alumel. Ice bath reference junctions were buried at the amplifier locations. Signal lines were well shielded. In spite of all precautions, a large amount of noise was encountered at the recording trailer where the signals were processed (fig. 9).

(2) Instrument Capabilities: Response time for the aspirated thermocouple was tested at the Forest Fire Laboratory where it was found that 24-gauge chromel-alumel aspirated thermocouples at about 60 feet per second required 3.75 seconds to reach 63 percent of step decrease. The digital voltmeter required 20 milleseconds to convert.

(3) Data: The data signals were processed with an analog-to-

digital converter before being recorded on punched paper tape in binary code counts. The counts were transferred to magnetic tape and computer machine listings. Each total binary code count multiplied by 0.2 results in readings in millivolts. The noise level exceeded the signal level; therefore the data could not properly be filtered.

(4) Volume of Data: 20 pages of computer listings.

f. Soil Temperature:

(1) Method: Six pairs of sealed chromel-alumel thermocouples were placed in the soil to measure heat transfer into the ground. Three pairs were placed under piles G-7, L-7, and O-7, and three pairs in the aisles next to these piles (fig. 11). A pair consisted of one unit buried 2 inches below the surface and one 6 inches below the surface. Signals from these thermocouples were transmitted to the recording trailer over shielded wire. Signals were scanned into potentiometric recorders.

(2) Instrument Capabilities: Thermocouple gauge was AWG #24. Recorder response time was 1 second for a full-scale deflection.

(3) Data: Data signals from the thermocouples were recorded at 30-second intervals on a strip chart recorder.

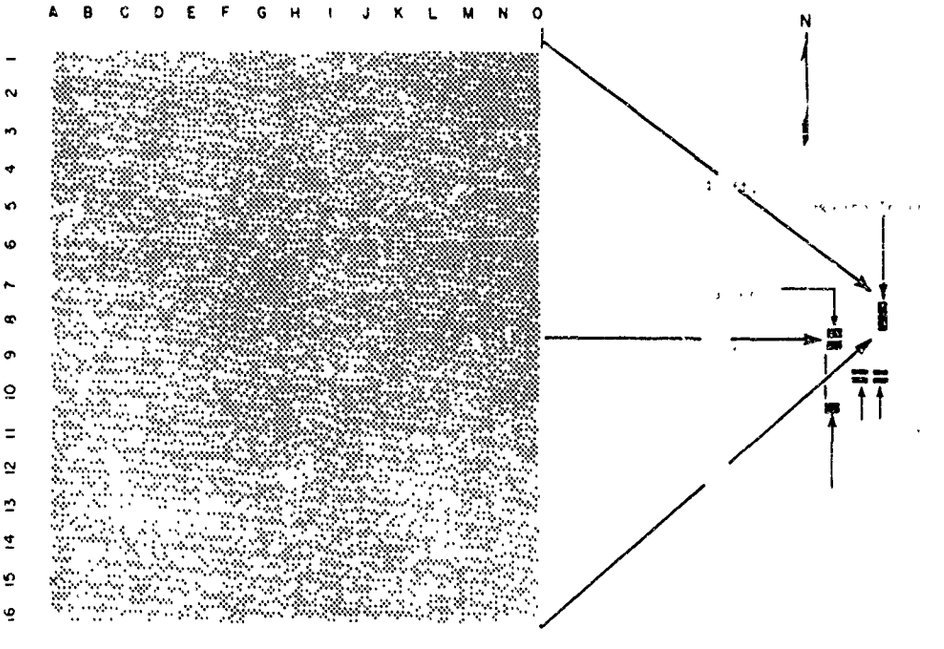


Figure 11.--Trailers placed at various distances from the pile housed instrumentation in Experimental Fire 466-7-66.

(4) Volume of Data: Two strip charts.

g. Flame Temperature:

(1) Method: Platinum-platinum, 13 percent rhodium thermocouples were used to measure the flame temperature. These devices were sealed sheath, insulated thermocouples made of 36-gauge wire. The outside diameter of the sheath was 0.40 inch, and gave a response time of about 8 seconds. Three of these thermocouples were suspended on stainless steel pipe towers 10 feet above ground level on piles G-7, L-7, and O-7, where amplified signals were sent to the recording trailers (fig. 11) over shielded wire (fig. 9). Each signal was recorded continuously on an individual strip chart recorder.

(2) Instrument Capabilities: The platinum-platinum rhodium thermocouples could measure temperatures to above 3,000°F. The recorders used had an accuracy of ± 0.25 percent.

(3) Data: Flame temperature data were recorded on strip charts. Processed data consist of computer listings. Noise level interferred with signal so that data could not properly be filtered.

(4) Volume of Data: 20 pages of computer listings, listed with gas temperature.

h. Air Flow:

(1) Method: Air speeds were measured at 72 locations on 32 towers (fig. 9). Bi-directional fan-type anemometers were operated in three's--one was oriented north-south, one east-west, and one vertical component. The device contains two reed switches closed by rotating magnets. The direction of rotation is determined by the sequence of reed switch closure and the speed of rotation by the frequency of closures. Reed switch performance is degraded by temperatures above 500°F., but is restored as the temperatures drop. Hence, units exposed to high temperatures were insulated. All sensors were sampled for 2 seconds, and then time was punched onto the tape along with an identifier. All data taken during the sampling period were then recorded on punch tape. The entire sequence required less than 10 seconds. The clock was set to record once every 10 seconds.

(2) Instrument Capabilities: Response of the bi-directional anemometers used was tested in the wind tunnel at the Forest Fire Laboratory. Characteristics are given in Test Fire 760-1-64 (fig. 3).

(3) Data: Airflow data were recorded on punch tape at 10-second intervals. Raw data from the three bi-directional sensors, together with calibration data, were used to determine horizontal

and vertical airflow angles, speed components, and vector speed. Processed data consist of magnetic tape and computer machine listings.

(4) Volume of Data: 3,000 pages of processed computer listings.

1. Pressure

(1) Method: Pressure transducers were installed along the east-west transect at 11 locations and also under pile L-7 (fig. 9). Two types of devices were used: barometric pressure transducers set up to read and record, plus or minus 1 inch of mercury; and differential pressure transducers. The barometric pressure transducers contain a bellows which is coupled to a rotary differential transformer. The response time is about $\frac{1}{2}$ second. To overcome friction in the bearings, a dither is incorporated into the unit. The differential pressure transducers required a connection to a reference line which was buried in the trench with the wiring. This type of unit contains a differential transformer in which the core is the pressure sensitive diaphragm. The reference line was terminated in a metal sphere buried 2 feet under the ground at the instrument trailer. The sphere was vented to atmospheric pressure and resealed immediately before ignition. The full-scale range set for this type of instrument was plus or minus .2 inch of mercury. In addition, three manually read manometers were read and recorded at 1-minute intervals throughout the fire.

All pressure transducers were vented to the atmosphere with stainless steel tubes. A small wad of stainless steel wool was placed in the ends of the vent pipes to reduce the effect of wind blowing across the tube ends. A separate pressure recording device 2 miles from the fire area recorded changes in atmospheric pressure.

(2) Instrument Capabilities: The recorders used with this system had a full-scale response time of 5 seconds.

(3) Data: Data were to have been recorded from each transducer on separate strip charts.

(4) Volume of Data: None.

Fuel Moisture:

(1) Method: Fuel samples were taken from within the plot area and later at the Forest Fire Laboratory the fuel moisture was determined by xylene reflux distillation.

(2) Instrument Capabilities: Results are reproducible to within less than 1 percent. Absolute calibration methods have not been determined.

(3) Data: Data were recorded manually on tabulation sheets.

(4) Volume of Data: 1 page.

k. Convection Column Temperature:

(1) Method: A radio telemetering rocket was used as an experimental temperature measuring device. It consisted of a .010-inch diameter thermistor mounted on the tip of a cold propellant rocket. The thermistor used has a time constant of one-half second in still air and about 50 milleseconds when aspirated at 200 feet per second. This time constant would allow about a 10-foot response time. The change in resistance of the thermistor was used to modulate a radio signal in the 27-megahertz band. The recorder used with this system could make a full-scale excursion in 125 ms. This capability would increase the overall response to 25 feet. Full-range was set to 50°F. to 450°F.

(2) Instrument Capabilities: Unknown. No successful flights have been made to date.

(3) Data: An Esterline Angus Speed Servo Recorder was used. Three rockets failed and one worked a short time. There was an extreme noise condition--possibly caused by the fire--on the receiving radio.

(4) Volume of Data: None.

l. Smoke Rockets:

(1) Method: Smoke rockets were launched from two points, 200 feet north and 200 feet east of the plot, at intervals during the fire. These were cold propellant rockets with aluminum power "smoke" generators attached. They were designed to release a visible trail to about 1,000 feet above ground (fig. 9).

(2) Instrument Capabilities: A visible "smoke" trail could be released to an altitude of about 1,000 feet above the launch site.

(3) Data: None available.

m. Photography:

(1) Method: Figs. 12 and 13 give camera station locations. In addition to the cameras listed in the chart below, aerial and ground documentary photography was recorded by 16-mm cameras.

Camera Station	Frames per Second	Film Size mm
1	12	16
2	12	16
3	12	16
4	12	16
	1 per 4 sec.	35
5	1 per 4 sec.	35
7	12	16
8	12	16

(2) Instrument Capabilities: No data are available on the accuracy of the cameras that were used on any specific station.

(3) Data: Usable data were obtained from all cameras. No clocks or time checks were recorded on the film.

(4) Volume of Data:

Camera Station	Original	Copy
1	200 ft.	5
2	1200 ft.	1
3	400 ft.	1
4	1200 ft.	1
	160 slides	1
5	173 slides	1
7	1200 ft.	1
	400 ft.	2
8	1200 ft.	1

6. Security Clearance: Unclassified.

7. Volume of Records: 526 pages of tabulated sheets, 3,020 pages of computer listings, 5,800 feet of movie film, and 333 slides.

8. Data Released: June 30, 1968.

9. Cooperators' Studies:

   a. Gas sampling, by UCLA Engineering Department.

   b. Infrared sensing, by Boeing Company, Wichita, Kansas.

   c. Fire whirl propagation and photographic observation, by NRDL.

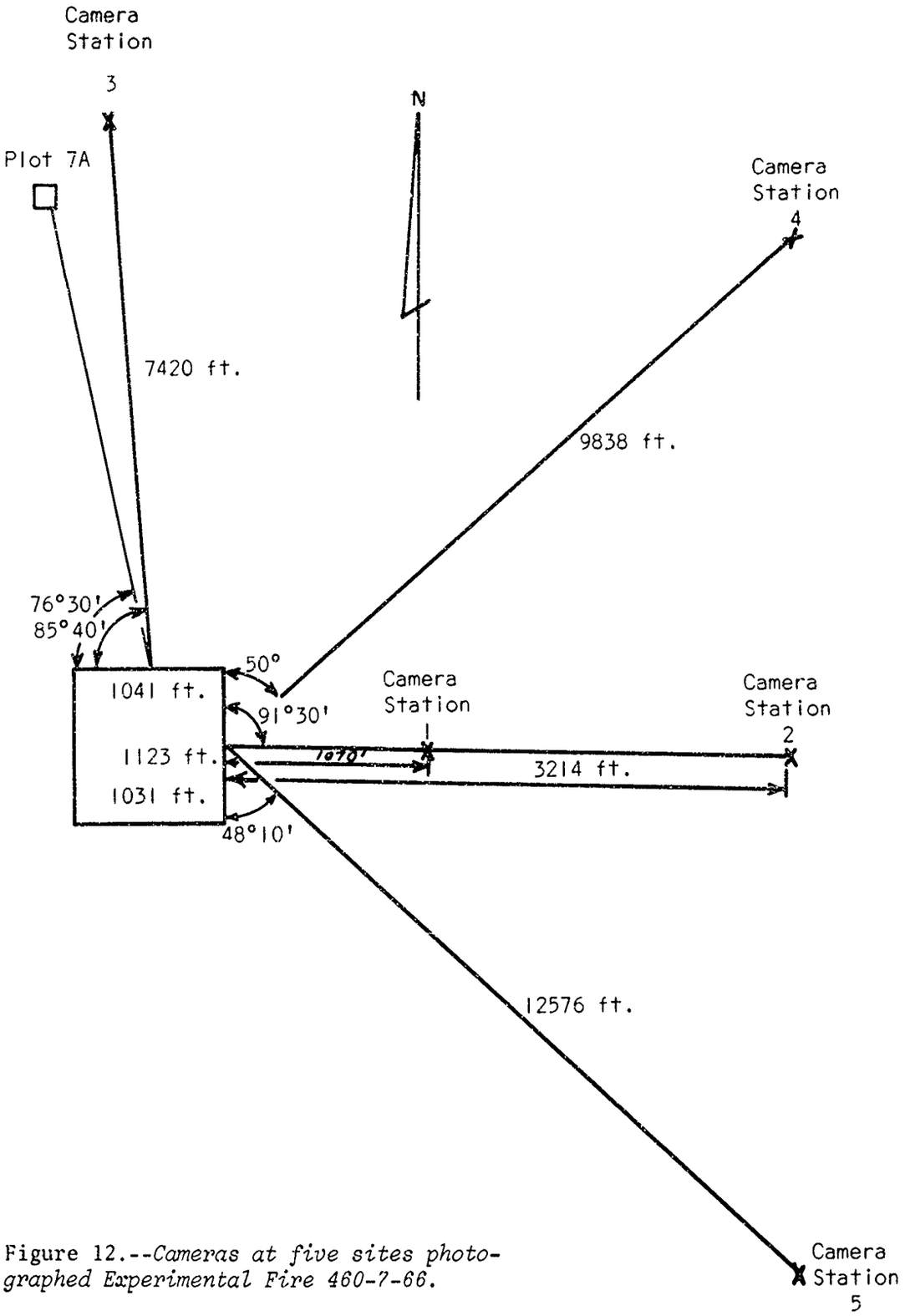


Figure 12.--*Cameras at five sites photographed Experimental Fire 460-7-66.*

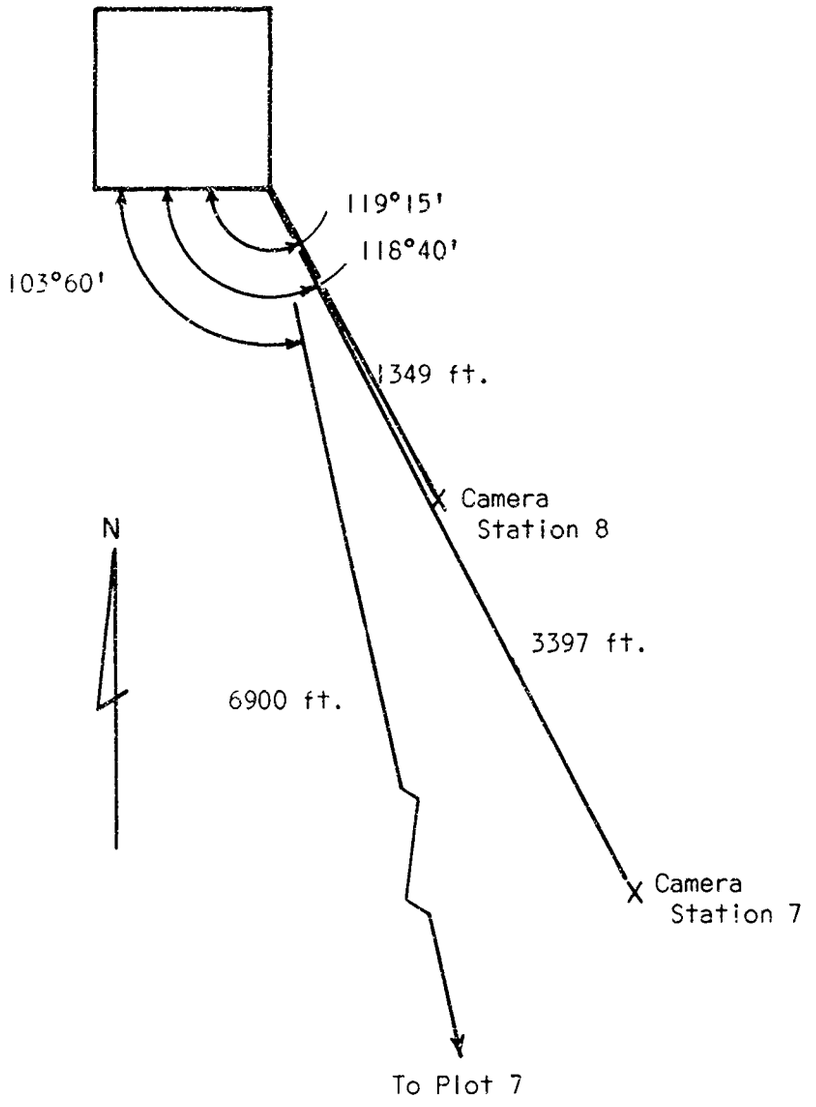


Figure 13.--*Cameras at two sites photographed Plot 7A burned simultaneously with Plot 7 in Experimental Fire 460-[illegible].*

d. Aerial and infrared photography, by El Toro U.S. Marine Corps Air Station under direction of NRDL.

e. Synoptic weather pattern, atmospheric measurements, and mesoscale analysis, by Fire Meteorology Project, Pacific Southwest Forest and Range Experiment Station, Riverside, California.

Experimental Fire SR-3-67

1. Test Data:

   a. Area covered: single plot.

   b. Ignited at 1330 PDT, June 8, 1967.

   c. Location: Queens Valley Ranch, Township 1 North, Range 33 East, Section 18, MDM, Mineral County, Nevada

   d. Elevation: 6,600 feet.

   e. Test Plots: single plot, SR-3, consisting of four 6- by 6-foot cribs on a 15- by 15-foot weighing platform. Each crib was layered with about 20 pounds of excelsior.

2. Project Number: OCD-PS-64-24, 32; OCD-PS-65-32, Forest Service Contract 12-11-0215-16 and 17, DASA EO 850-67 and 68, Forest Service letter of June 13, 1966, and "A Program for Mass Fire Behavior Research" of May 1966.

3. Project Officer: Thomas Y. Palmer (formerly E. M. Gaines)

4. Types of Measurements:

   a. Fuel Weight Loss

      (1) Method: The 15- by 15-foot weight loss platform was mounted on four Toledo precision load cells with about 5,000 pounds on each load cell. Precision power supplies which were temperature-compensated were used to excite the 5,000-pound capacity load cells. Teflon-to-Teflon slip joints were used to relieve side loading effects caused by expansion and contraction of steel in the platform.

      Data were transmitted over shielded wire and recorded on an Esterline Angus Speed Servo potentiometer. Signals from all four load cells were summed to give one continuous recording.

      (2) Instrument Capabilities: The Esterline Angus Speed Servo recorder had a full-scale response time of 200 milliseconds. Minimum resolution was ± 3.5 pounds.

      (3) Data: Recorded on strip charts for 146 minutes.

      (4) Volume of Data: 1 strip chart. On file at Forest Fire Laboratory, P.O. Box 5007, Riverside, California 92507.

b. Thermal Radiation

(1) Method: Thermal radiation was measured at 20 feet from the corner of the weighing platform. A Beckman-Whitley Model N-188 flatplate radiometer was installed at the 3-foot elevation.

Both radiation measurements and plate temperature corrections were recorded on Esterline Angus Speed Servo potentiometric recorders. The device had a 125-millisecond response time.

(2) Instrument Capabilities: The Beckman-Whitley flatplate radiometer used has a response time of about 0.2 minute for 63 percent of step increase. The maximum thermal radiation allowable is limited by the plate temperature rise. Plate temperature is limited to 240° F.

(3) Data: Data were recorded on strip charts for 70 minutes. Processed data are on recorder charts.

(4) Volume of Data: Two rolls of recorder charts on file at Forest Fire Laboratory, P. O. Box 5007, Riverside, California 92507.

Experimental Fire SR-5-67

1. Test Data:

a. Area covered: single plot.

b. Ignited at: 0803 PDT, August 10, 1967

c. Location: Queens Valley Ranch, Township 1 North, Range 33 East, Section 18, MDM, Mineral County, Nevada

d. Elevation: 6,600 feet.

e. Test Plots: single plot, SR-3, consisting of four 6- by 6-foot cribs on a 15- by 15-foot weighing platform; each crib was layered with about 20 pounds of excelsior.

f. Project Number: OCD-PS-64-24 and 32, OCD-PS-65-32, Forest Service Contract 12-11-0215-16 and 17, DASA EO 850-67 and 68, Forest Service letter of June 13, 1966, and "A Program for Mass Fire Behavior Research" of May 1966.

3. Project Officer: Thomas Y. Palmer (formerly E. M. Gaines)

4. Types of Measurements:

a. Fuel Weight Loss

(1) Method: The 15- by 15-foot weight loss platform was mounted on four Toledo precision load cells with about 3,000 pounds on each load cell. Precision power supplies which were temperature-compensated were used to excite the 5,000-pound capacity load cells. Teflon-to-Teflon slip joints were used to relieve side loading effects caused by expansion and contraction of steel in the platform. Data were transmitted over shielded wire and recorded on an Esterline Angus Speed Servo potentiometer. Signals from all four load cells were summed to give one continuous recording.

(2) Instrument Capabilities: The Esterline Angus Speed Servo recorder had a full-scale response time of 200 milliseconds. Minimum resolution was ± 3.5 pounds.

(3) Data: Recorded on strip charts for 146 minutes.

(4) Volume of Data: 1 strip chart. On file at Forest Fire Laboratory, P. O. Box 5007, Riverside, California 92507.

b. Thermal Radiation

(1) Method: A Beckman-Whitley Model N-188 flatplate radiometer was installed at the 3-foot elevation. Thermal radiation was measured at 20 feet from the corner of the weighing platform. Both radiation measurements and plate temperature corrections were recorded on Esterline Angus Speed Servo potentiometric recorders. The device has a 125-millisecond response time.

(2) Instrument Capabilities: The Beckman-Whitley flatplate radiometer used has a response time of about .2 minutes for 63 percent of step increase. The maximum thermal radiation allowable is limited by the plate temperature rise. Plate temperature was limited to 240° F.

(3) Data: Recorded on strip charts for 70 minutes. Processed data are on recorder charts.

(4) Volume of Data: Two rolls of recorder charts on file at Forest Fire Laboratory, P. O. Box 5007, Riverside, California 92507.

Experimental Fire 760-12A1-67

1. Test Data:

   a. Area covered: single plot.

   b. Ignited at: 0930 PDT, August 29, 1967

   c. Location: southwest corner of Township 2 North, Range 32 East, Section 26, MDM, near Basalt, Mineral County, Nevada, about 70 miles north of Bishop, California.

   d. Elevation: 7,500 feet.

   e. Test Plots: single plot, 12A1, consisting of milled fuel arranged in 49 cribs on a weighing platform; each 6- by 6-foot crib layered with about 20 pounds of excelsior (fig. 14; table 3).

2. Project Number: OCD-PS-64-24, 32; OCD-PS-65-32, Forest Service Contract 12-11-0215-16 and 17, DASA EO 850-67 and 68, Forest Service letter of June 13, 1966, and "A Program for Mass Fire Behavior Research" of May 1966.

3. Project Officer: Thomas Y. Palmer (formerly E. M. Gaines)

4. Types of Measurements:

   a. Fuel Weight Loss:

      (1) Method: The weight loss platform measured 48 by 48 feet and was mounted on four Toledo precision load cells. The weight on each load cell was approximately 26,000 pounds. The load cells were symmetrically spaced 12 feet in from the sides of the platform, allowing 24 feet between cells. Concrete piers supported the cells. Teflon-to-Teflon slip joints were fabricated on 9- by 1-inch circular steel plates installed between the cells and platform to relieve side load stresses on the load cells.

      Precision, temperature-compensated power supplies were used to excite the cells. High quality, direct current amplifiers with a gain setting of X166.6 were used to give a signal level of 2.500 volts per 25,000 pounds load for each cell. Signals were transmitted over shielded wires.

      Signals were converted to a binary coded decimal form with a Digitec Model 252 Digital Voltmeter which recorded data at 10-second intervals on an 8-level tape punch. Time information was recorded at the beginning of each recording sequence.

(2) Instrument Capabilities: Using a digital voltmeter with 1 millivolt resolution ± one count, the minimum measurable weight change that could be measured was about 20 pounds out of the total load, per load cell. Aerodynamic effects on the platform tended to obscure this accuracy. The load cell and amplifier response times were very good, but the digital voltmeter required about 20 milliseconds to make conversion. The entire system was limited by the 10-second cycle time of the programing device.

(3) Data: Recorded on punched paper tape at 10-second intervals from 5 minutes before ignition, continuing until 1 hour and 41 minutes after ignition. Processed data consist of listings and cards.

(4) Volume of Data: 13 pages of computer listings. Located at Forest Fire Laboratory, P. O. Box 5007, Riverside, California 92507.

b. Thermal Radiation:

(1) Method: Thermal radiation was measured from a tower 50 feet east of the platform. A Beckman-Whitley Model N-188 flatplate radiometer was installed at the 10-foot elevation.

Both radiation measurements and plate temperature corrections were recorded on Esterline Angus speed servo 125-millisecond response time potentiometric recorders. The instrument was sampled for 2 seconds with a 2-second return to 0 reference at the end of a scan. The radiation was sampled for 2 seconds once each 10 seconds.

(2) Instrument Capabilities: The Beckman-Whitley flatplate radiometer used has a response time of approximately 0.2 minute for 63 percent of step increase.

The maximum thermal radiation allowable was limited by the plate temperature rise. Plate temperature was limited to 240° F.

(3) Data: Data were recorded on strip charts for 2 seconds each 10 seconds during the fire. Processed data are on tabulated sheets.

(4) Volume of Data: One strip chart. Located on file at Forest Fire Laboratory, P. O. Box 5007, Riverside, California 92507.

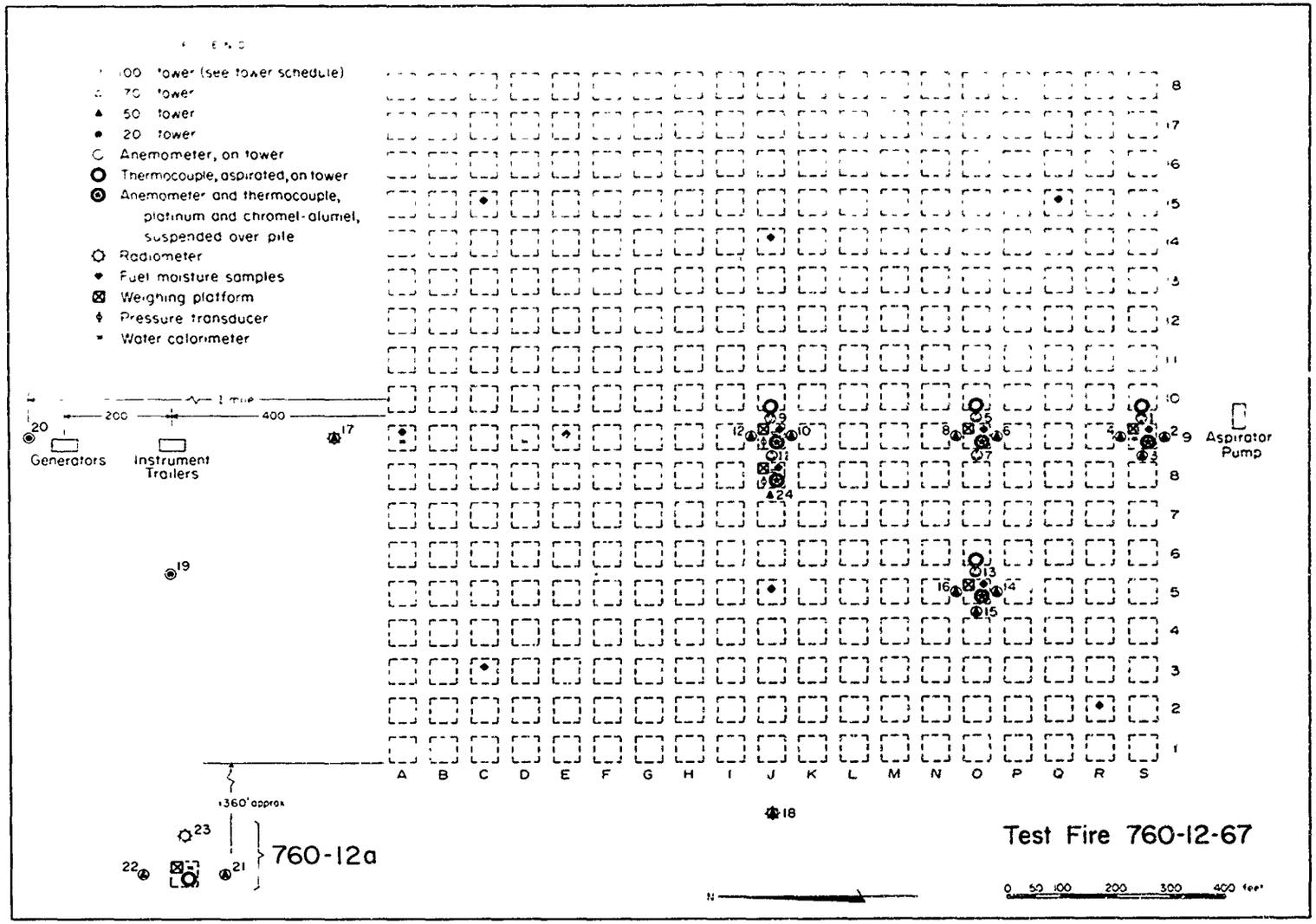


Figure 14.--*Plot layout for Experimental Fire 760-12-67, August 29, 1967.*

Table 3.--Tower schedule for Experimental Test
Fire 760-12-67, August 29, 1967

TOWER NUMBER	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
HEIGHT (ft.)	100	50	50	50	70	50	70	50	100	50	70	50	70	50	50	50	50	50	20	20	50	50	10	50
ANEMOMETERS																								
3.5 ft.	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x					x	x		
7	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x					x	x		
20	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x			x	x	x	x		
50	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x					x	x		
70					x		x						x											
80	x								x		x													
100	x								x															
ASPIRATED THERMOCOUPLES																								
3.5 ft.	x				x				x				x											
7	x				x				x				x											
20	x				x				x				x											
50	x				x				x				x											
70					x								x											
80	x								x															
100	x								x															
RADIOMETER																								
10 ft.																	x	x					x	
50																	x	x						

Experimental Fire 760-12-67

1. Test Data:

   a. Area covered: 50 acres.

   b. Ignited at: 0757 PDT, September 29, 1967.

   c. Location: southwest corner of Township 2 North, Range 32 East, Section 26, MDM, near Basalt, Mineral County, Nevada, about 70 miles north of Bishop, California.

   d. Elevation: 7,500 feet.

   e. Test Plots: 342 piles of fuel (four of them of milled fuel, the remainder of pinyon pine and Utah juniper), each 48 feet square and about 20 tons (dry weight); arranged in 18 rows in one direction and 19 in the other, 25 feet apart and from 5 to 7 feet tall (fig. 14).

2. Project Number: OCD-PS-64-24 and 32, OCD-PS-65-32, Forest Service Contract 12-11-0215-16 and 17, DASA EO 850-67 and 68, Forest Service letter of June 13, 1966, and "A Program for Mass Fire Behavior Research" of May 1966.

3. Project Officer: Thomas Y. Palmer (formerly E. M. Gaines).

4. Types of Measurements:

a. Fuel Weight Loss:

(1) Method: Five weight loss platforms, each 48 x 48 feet and mounted on Toledo precision load cells, were used on milled-fuel piles J-9, O-9, S-9, O-5, and on wildland-fuel pile J-8 (fig. 14).

Weight on each load cell was approximately 26,000 pounds, including fuel, and was symmetrically distributed 12 feet in from the sides of the platform, allowing 24 feet between cells. Concrete piers supported the cells. Teflon-to-Teflon slip joints were fabricated on 9- by 1-inch circular steel plates installed between the cells and platform to relieve side load stresses on the load cells.
Precision, temperature-compensated power supplies were used to excite the cells. High quality, direct-current amplifiers with a gain setting of X166.6 provided a signal level of 2.500 volts per 25,000 pounds load for each cell. Signals were transmitted over buried, shielded wires (fig. 15).

The signals were converted to a binary coded decimal form with a Digitec Model 252 Digital Voltmeter which recorded data at 10-second intervals on an 8-level punch tape. Time information was recorded at the beginning of each recording sequence.

The platform was calibrated before loading the fuel by weighing two Jeeps and a large generator on a separate standard load cell. The vehicles and generator were then placed on the weighing platform and the deflection recorded as a three-point calibration.

(2) Instrument Capabilities: By using a digital voltmeter with 1 millivolt resolution ± one count, the minimum weight change that could be measured per load cell was about 20 pounds out of the total load. Aerodynamic effects on the platform tended to reduce this accuracy. The response times of the load cell and amplifier were good, but the digital voltmeter required about 20 milliseconds to convert, and the entire system was limited by the 10-second cycle time of the programing device.

(3) Data: Recorded on punched paper tape at 10-second intervals from 5 minutes before ignition and continuing until 4-1/2 hours after ignition. Processed data consist of listings and magnetic tape (7040 Fortran).

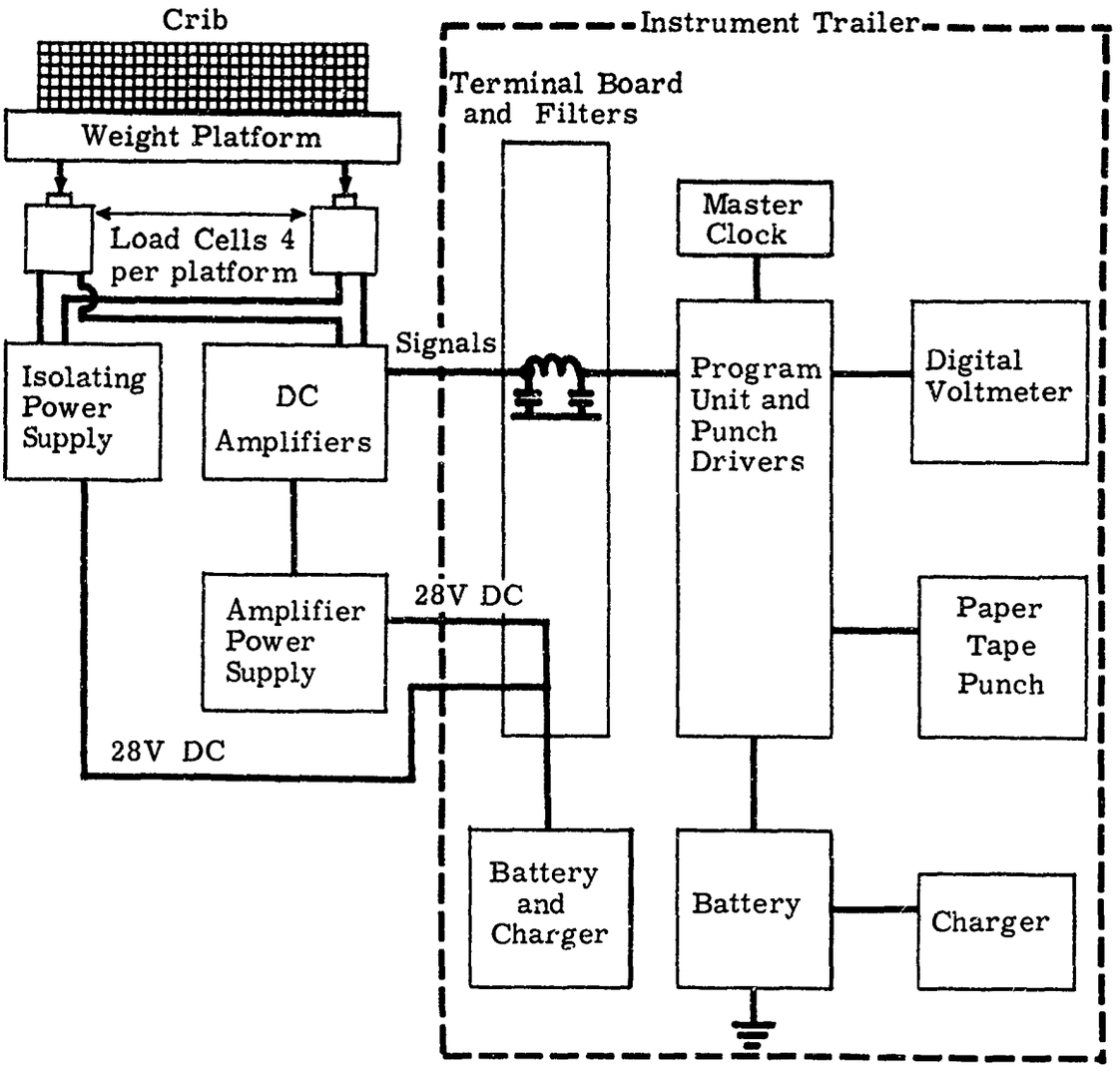


Figure 15.--*Fuel weight loss in Experimental Fire 760-12-67, on September 29, 1967, was measured by load cells and recorded by the instrument trailer.*

(4) Volume of Data: 20 pages of computer listings.

b. Thermal Radiation

(1) Method: Beckman-Whitley Model N-188 Flatplate Radiometers were installed 10 and 50 feet above the base of the tower 100 feet north and 100 feet west of the plot (fig. 14). Radiation measurements and plate temperature corrections were recorded on Esterline Angus Speed Servo recorders. They had a 125-millisecond response time. Each instrument was sampled for 2 seconds, with a 2-second return to zero reference at the end of a scan. Each radiometer was sampled for 2 seconds once every 10 seconds (fig. 16).

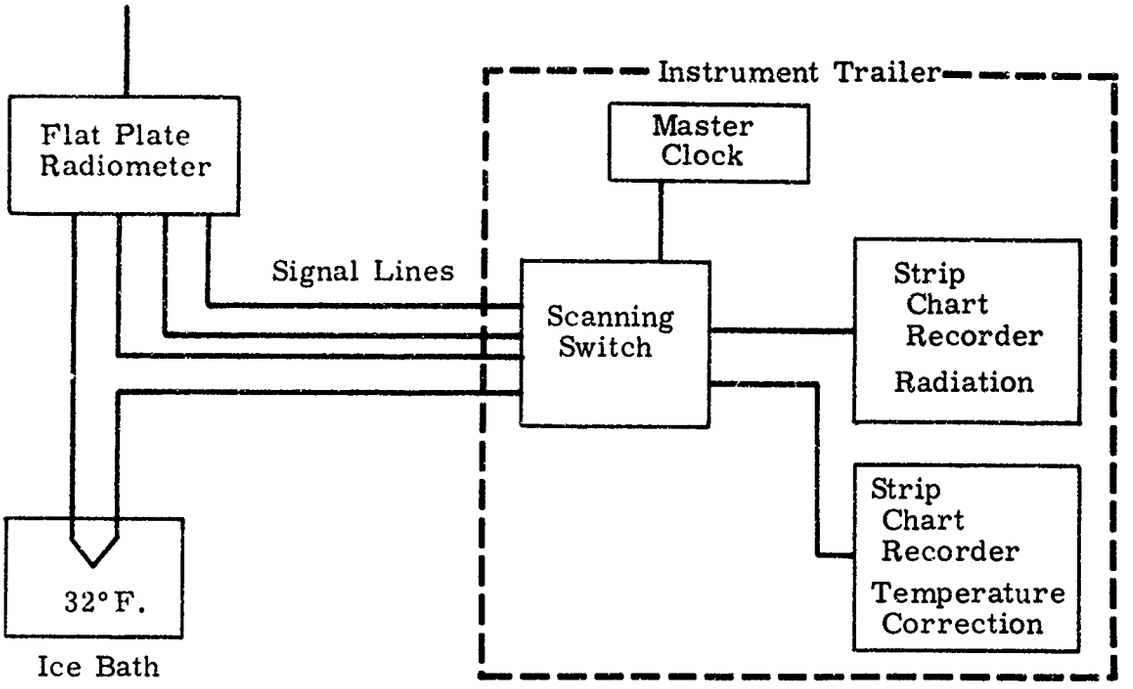


Figure 16.--*Radiometers, connected to the instrument trailer, measured thermal radiation in Experimental Fire 760-12-67.*

(2) Instrument Capabilities: The Beckman-Whitley flatplate radiometers had a response time of about 0.2 minute for 63 percent of step increase. The maximum thermal radiation allowable was limited by the plate tempererature rise. Plate temperature was limited to 240° F.

(3) Data: Recorded on strip charts for 2 seconds each 10 seconds during the fire. Processed data are on listings and cards.

(4) Physical Volume of Data: 12 pages of computer listings.

c. Water Calorimeter (Heat Output)

(1) Method: A 50-foot copper-nickel pipe, 5/8 inch in diameter outside and 1/2 inch inside, was suspended over a fuel bed and connected to a water supply and circulating pump. Water flow and inlet and outlet temperatures were measured over five fuel beds (fig. 14).

High precision-resistance thermometers immersed in the water stream at the ends of the 50-foot pipe served as sensors to measure water temperatures. Shielded wires were used to transmit the signals to the recording trailer (fig. 17).

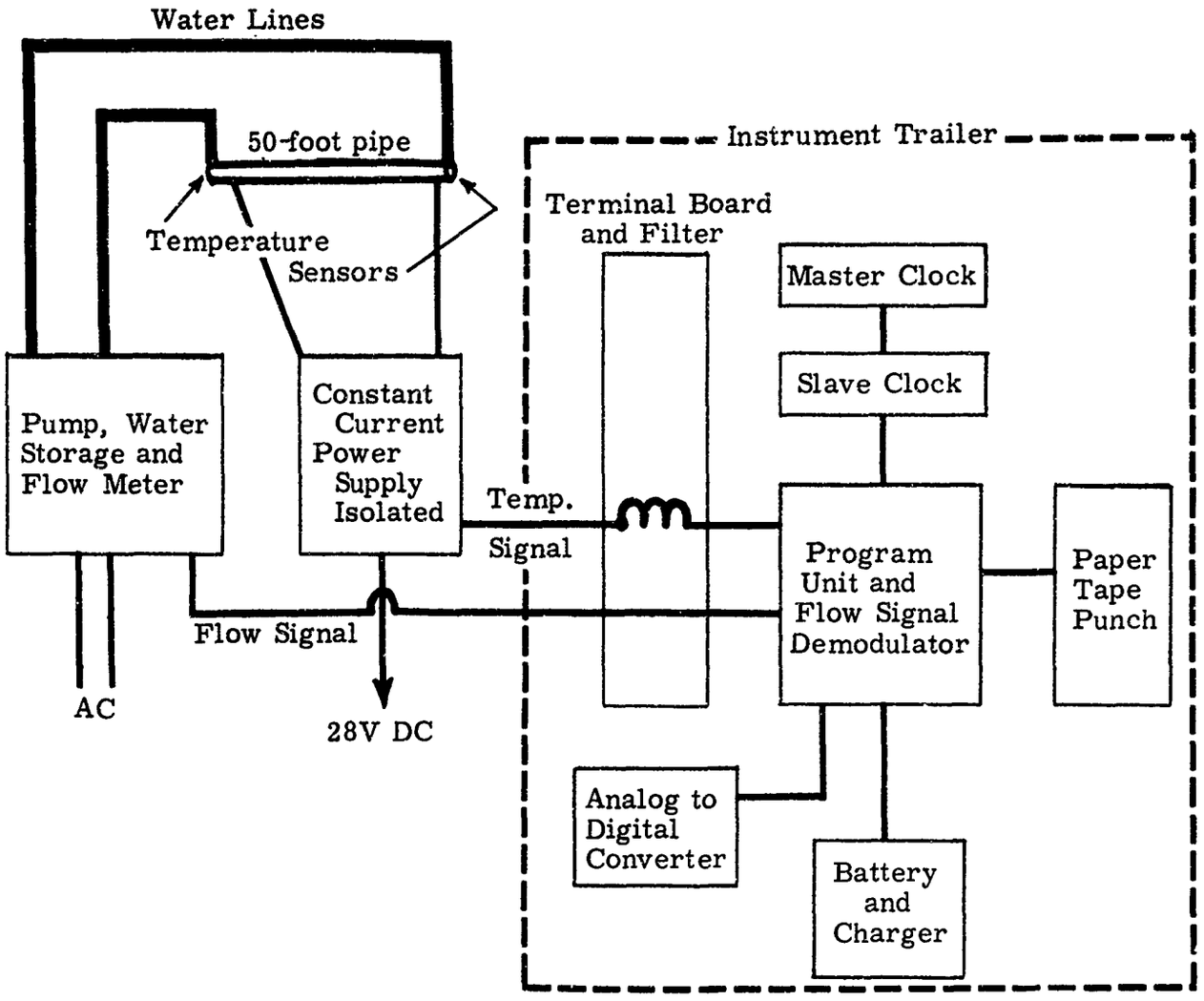


Figure 17.--*Heat output was measured by water calorimeters. Signals to the instrument trailer were transmitted by shielded lines.*

Signals at the trailer were filtered and inserted into a Non-Linear Systems Model 15BS721 A to D converter where they were recorded in 8-level binary code punched paper tape. Data on waterflow, temperature, and time were recorded.

(2) Instrument Capabilities: The water flow calorimeter was an experimental device designed, for reason of economy, to replace the weight loss platform. It could receive a temperature difference (hot end over cold end) of $1/2^{\circ}$ C. But its accuracy and precision have not been determined.

(3) Data: Recorded at 10-second intervals from 5 to 13 minutes on binary code punch tape. Processed data consist of listings and cards.

(4) Volume of Data: 5 pages of computer listings.

d. Gas Temperature:

(1) Method: Chromel-alumel thermocouples were used to measure gas temperature on towers 1 and 9 at 3.5-, 7-, 20-, 50-, 80-, and 100-foot levels. On towers 5 and 13, measurements were made at the 3.5-, 7-, 20-, 50-, and 70-foot levels (fig. 14). 24-gauge wire thermocouples were placed inside thin, double-walled stainless steel shields, with a ceramic felt-type insulation inserted between the walls. The inner tube had an inner diameter of 1/2 inch, and an outside diameter of 2 inches. The thermocouple junction was placed 8 diameters from the open end fig. 18).

A minimum aspiration rate of 60 feet per second was maintained by a pump situated 200 feet south of the plot, over the measuring junction.

Ice baths, in thermos bottles, were used as reference junctions. They were buried, along with amplifiers, near the base of the towers. Amplifier gain was set at X40 to increase signal levels for transmission over shielded wires. A Digitec Model 252 Digital Voltmeter converted the signals to binary coded decimal form. Signals were filtered to remove high frequency alternating current components.

(2) Instrument Capabilities: Response time for the aspirated thermocouple was tested at the Forest Fire Laboratory, where it was found that 24-gauge chromel-alumel aspirated thermocouples at a ventilation rate of 60 feet per second required 3.75 seconds to reach 63 percent of step decrease. The digital voltmeter required 20 milliseconds to convert.

(3) Data: The binary coded decimal data were recorded at 10-second intervals along with time information on an 8-level punched paper tape. The noise level interfered with the signal so that the data could not be filtered properly. A running 10-point quadratic fit to the data with 5-sigma test on data rejection are available.

Processed data consist of listings and magnetic tape (7040 Fortran).

(4) Volume of Data: 18 pages of listings, which includes some data on flame temperature (see Gas Temperature).

e. Flame Temperature:

(1) Method: Platinum thermocouples were placed at the 10-foot level over fuel piles S-9, O-9, J-9, and O-5, and chromel-alumel thermocouples over J-8. At the 40-foot level, bare

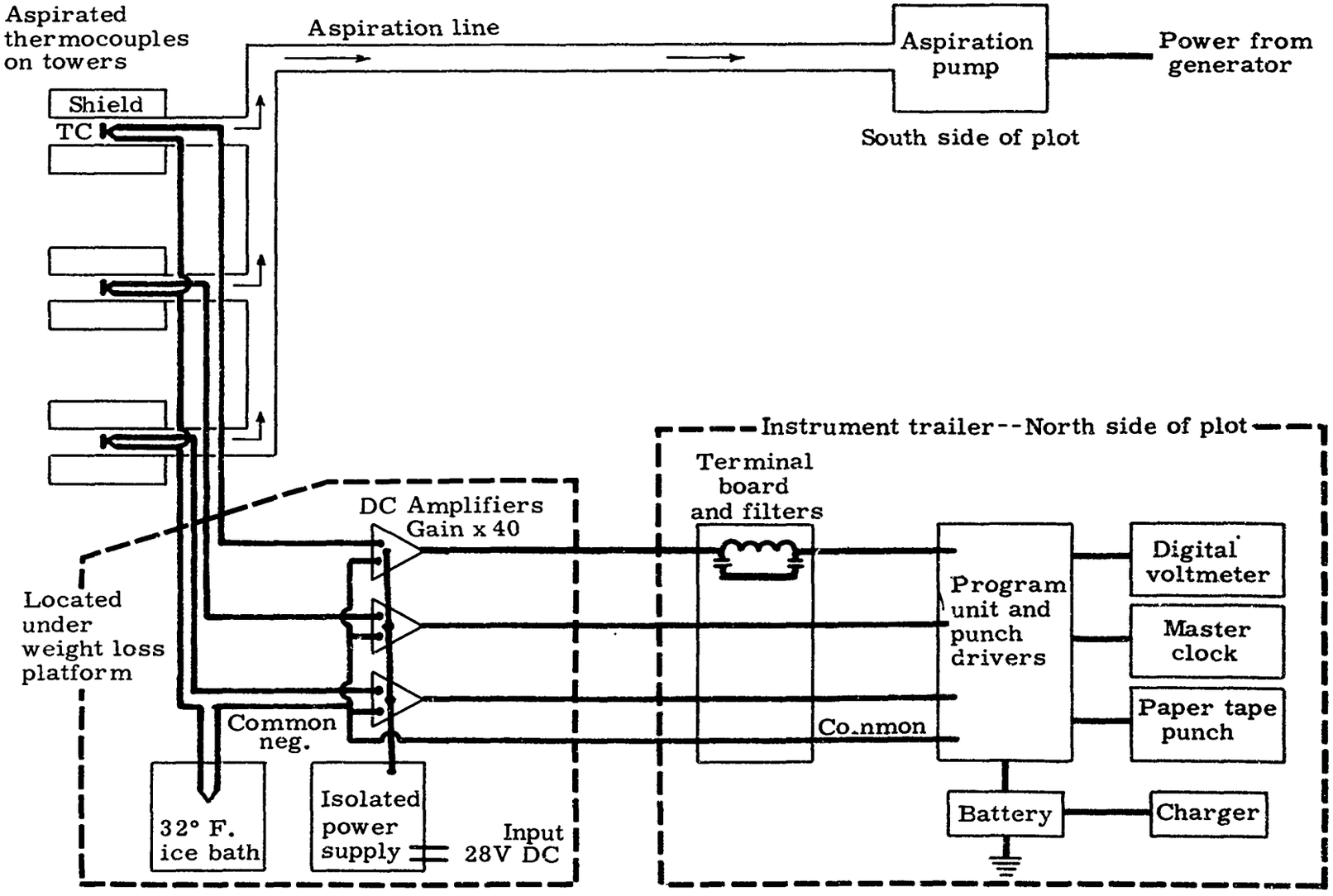


Figure 18.--*Aspirated thermocouples mounted on towers measured gas temperatures in Experimental Fire 760-12-67.*

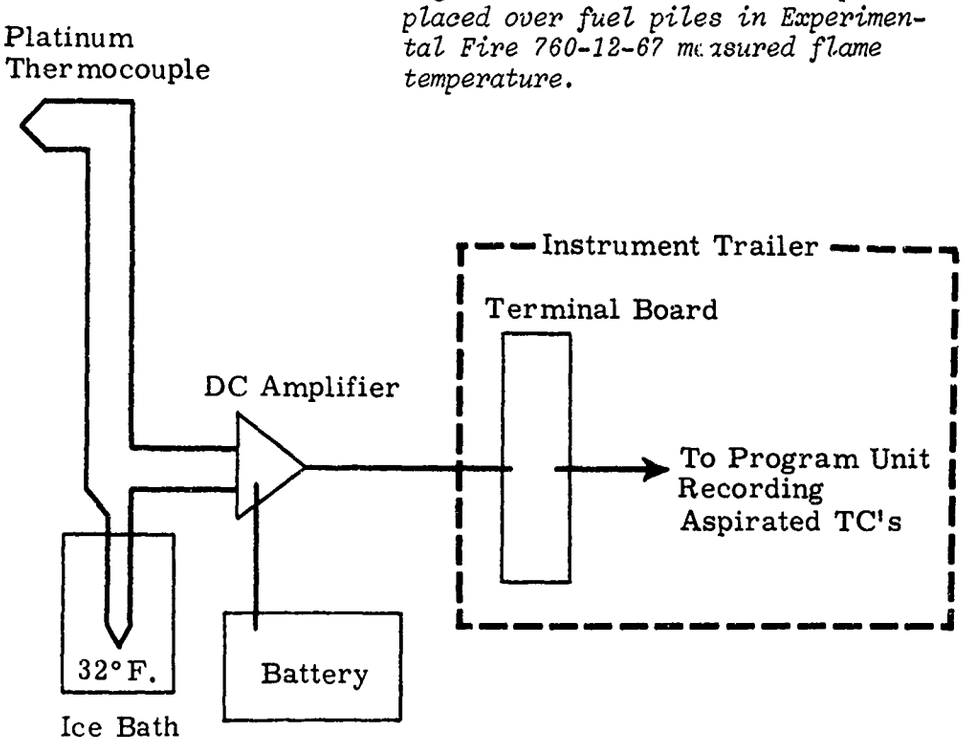
chromel-alumel thermocouples were placed over fuel piles S-9, O-9, J-9, O-5, and J-8 (fig. 14), in an effort to measure flame temperatures.
The platinum thermocouples were 0.4 inch in diameter, including sheath. The chromel-alumel thermocouples were 11-gauge wire. Both were referenced to 32° F. with a buried thermos bottle ice bath. Direct current amplifiers were used on all thermocouples, except the two bare chromel-alumel units over pile J-8 (fig. 19).

(2) Instrument Capabilities: Response times of the thermocouples were tested at the Forest Fire Laboratory. The 11-gauge chromel-alumel bare wire in still air took about 50 seconds to reach 63 percent of step decrease, the platinum-platinum-rhodium with platinum sheath took 8 seconds.

(3) Data: All thermocouple signals were recorded on punched paper tape along with the aspirated thermocouple signals except for the two bare thermocouples over pile J-8. These signals were recorded continuously on potentiometric strip chart recorders. Only one strip chart has available data owing to noise interference. Processed data consist of listings and magnetic tape (7040 Fortran).

(4) Volume of Data: 18 pages of listings, which includes some data on flame temperature, and one strip chart for pile J-8.

Figure 19.--*Platinum thermocouples placed over fuel piles in Experimental Fire 760-12-67 measured flame temperature.*



f. Air Flow:

(1) Method: Anemometers were attached by 3-foot booms to 18 towers and suspended by wires over four piles at levels ranging from 3.5 to 100 feet (fig. 14).

Data from 16 stations were sampled at the same time, with sampling time 2 seconds and recording time 8 seconds, and recorded each 10 seconds on punched paper tape (fig. 20). Data from two stations were recorded on strip charts. Each station had three units, one sensing N-S, one E-W, and one vertical components. The anemometers were insulated with 3/4-inch insulating castable refractory cement inside a stainless steel housing. All units were calibrated individually, and calibration curves are available for each unit.

(2) Instrument Capabilities: Lag distance of the bi-directional anemometers used was tested at the Forest Fire Laboratory. Results are shown in figure 3.

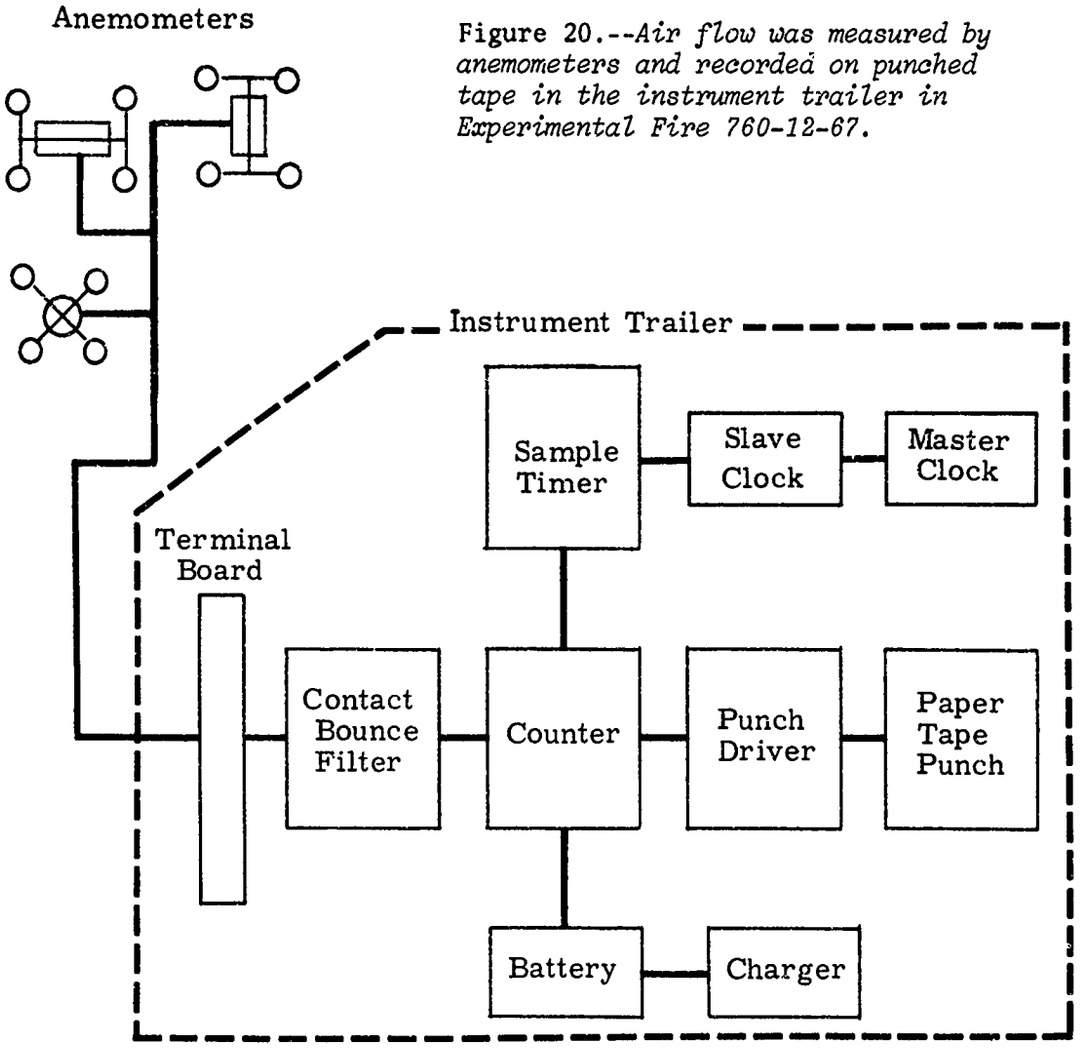


Figure 20.--*Air flow was measured by anemometers and recorded on punched tape in the instrument trailer in Experimental Fire 760-12-67.*

(3) Data: Data (except for towers 19 and 20 were recorded on punch tape in 8-level pure binary code at 10-second intervals for 4-1/2 hours. Processed data consist of listings and magnetic tape (7040 Fortran). Processed data for towers 19 and 20 are on tabulated sheets.

(4) Volume of Data: 4,000 pages of computer listings and 4 pages of tabulation.

g. Pressure:

(1) Method: A differential transducer was placed under piles J-8 and J-9 (fig.21). One side of the units was vented toward the top of the platform, the other toward the bottom. Ends of the vent tubes were plugged with ceramic felt to reduce the venturi effects of air flow over the vent.

In addition to the two units that were operated differentially, a third transducer was referenced to a sealed tank buried under the platform to sense changes in barometric pressure. The two differentially operated units were ± 5 psid transducers, and the one referenced to the sealed tank was 3.5 psid (fig. 21).

(2) Instrument Capabilities: Response time of the differential transducers was tested at the Forest Fire Laboratory, and it was found that they made an excursion from -1 psi to +1 psi in less than one-sixth of a second. When the ceramic felt was added the full-scale excursion fell off about 4 percent for the one-sixth second time. No change was observed for longer time ± 1 psi pressure changes.

(3) Data: Recorded along with the weight loss data on punched paper tape. Processed data consist of listings and magnetic tape (7040 Fortran).

(4) Volume of Data: 20 pages of computer listings.

h. Fuel Moisture:

(1) Method: Moisture samples were taken of milled and wildland fuel piles after which content was determined by xylene reflux distillation (see figure 14 for sampling locations).

Milled fuel piles contained excelsior and rough lumber ranging from 1/2 inch to 4 inches; whereas wildland fuel ranged from 1/4 inch to 6 inches of natural material.

(2) Instrument Capabilities: Results are reproducible to within less than 1 percent. Absolute calibration methods have not been determined.

(3) Data: Recorded manually on a tabulated sheet.

(4) Volume of Data: 1 page.

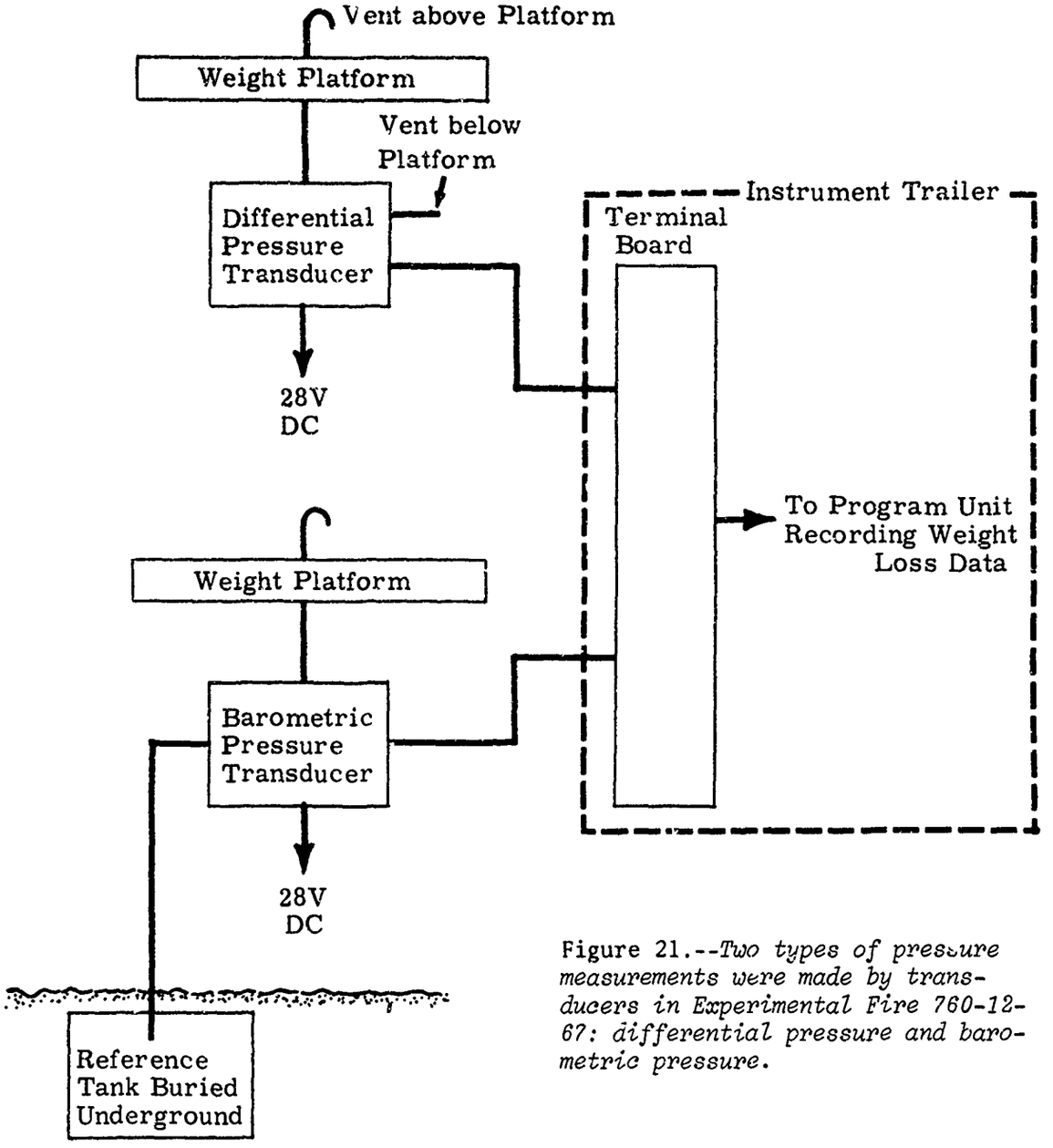


Figure 21.--*Two types of pressure measurements were made by transducers in Experimental Fire 760-12-67: differential pressure and barometric pressure.*

i. Weighing Platform Material Moisture Content:

(1) Method: Samples were taken of brick insulators, soil mantle, and decking of the weighing platforms before and after the test burn (fig. 14). Samples were sealed in plastic containers and taken to the Forest Fire Laboratory for processing.

Brick insulators: Samples were taken September 28 from the center of each side of the platform. The day after the burn samples were taken at the same locations as well as 15 feet toward the center on each side.

Soil mantle: Samples were taken in and around piles A-9, C-3, C-15, E-9, J-5, J-14, Q-15, and R-2. Orientation of sampling line was selected randomly from 20 feet beyond the northeast corner to 20 feet beyond the southwest corner, with four samples taken on the platform.

Samples were taken under and near the edges of piles J-8, J-9, O-5, O-9, and S-9. All samples were taken September 28 and September 30.

Decking: Samples were obtained by drilling to the center of a wood plank and collecting the shavings. It was often necessary to drill three to six holes in each plank to obtain 110 grams of material to provide an adequate sampling.

Samples were taken at three locations on each platform before the test: NE, SW, and center. After the burn they were taken at two locations to determine variance between the September 21 and 28 samples.

(2) Instrument Capabilities: Not applicable.

(3) Data: Taken manually and recorded on tabulated sheets.

(4) Volume of Data: 34 tabulated sheets.

5. Photography:

a. Method: Four types of cameras were used at seven locations (fig. 22). In addition, two 16 mm cameras were used for documentary (table 4). The Arriflex cameras were operated by 8-volt direct current variable speed, governor-controlled battery-powered motors. The Veritron cameras were powered by 24-volt batteries and pulsed by a timer. The Nikon cameras were operated by a battery-powered motor pack, with a B-3 Intervoltmeter device which controlled the frames per second. The Milliken camera was battery-powered.

b. Instrument Capabilities: Arriflex: The accuracy of the tachometer used to measure frames per second is not known, but it is believed that error of less than 5 percent at eight frames per second would be a reasonable estimate.

To maintain a constant reading on the tachometer, it was necessary to adjust the variable speed motor during the filming operation because of the voltage drop in the battery power supply. Accuracy of the camera thereby depended on the operator.

Veritron: No usable data are available due to malfunction.

Nikon: Battery-powered motor packs were used along with an intervoltmeter to control frames per second. Data are not available regarding the accuracy of the intervoltmeter.

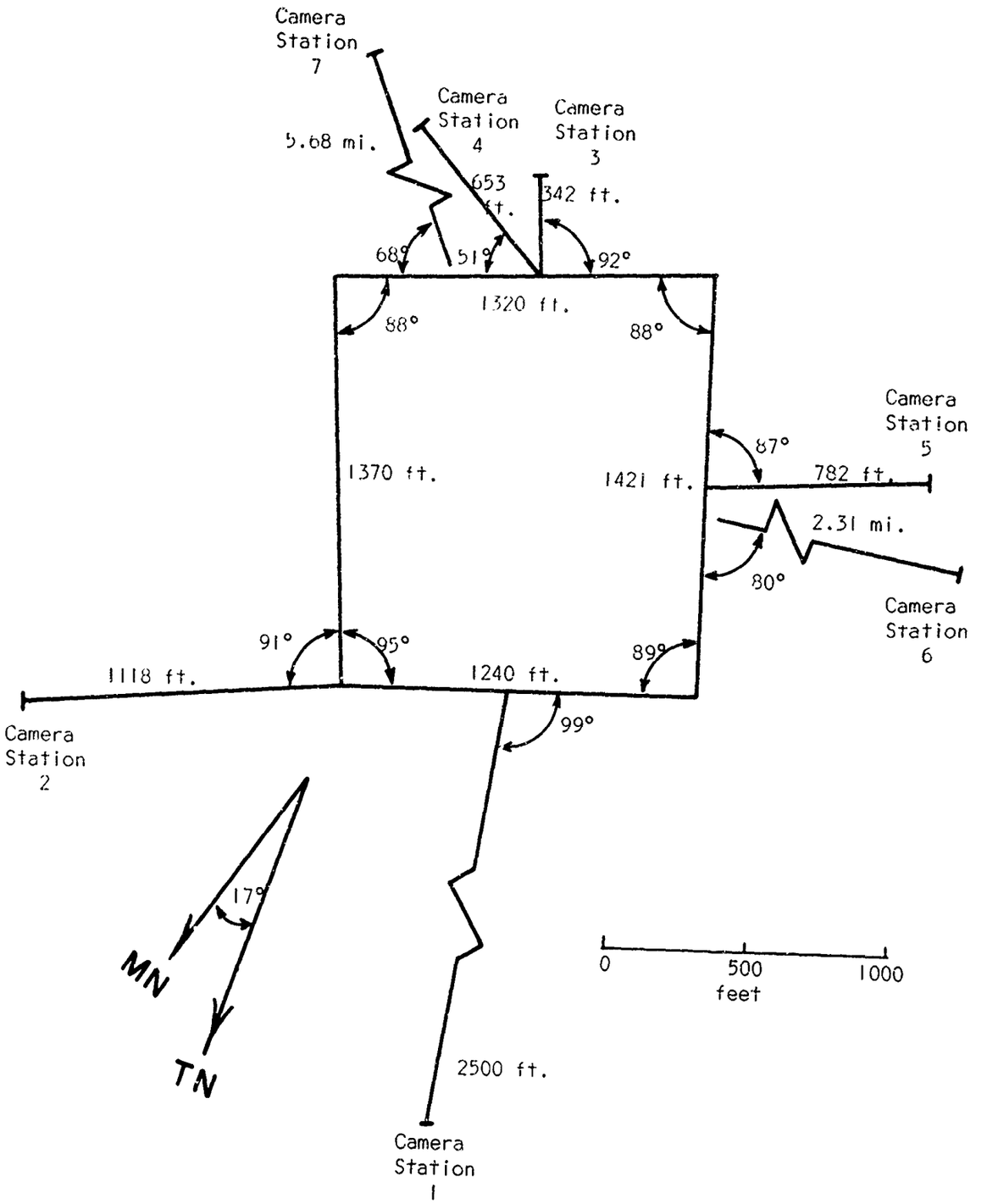


Figure 22.--*Cameras were set up in seven locations in Experimental Fire 760-12-67.*

Table 4.--Cameras and film used in Experimental Fire 760-12-67, September 29, 1967

Camera station and name	Lens	Shutter speed	Frames per sec.	F stop	Filter	Film type	ASA	Film size
	mm	Sec.			No.		No.	mm
1:								
Arriflex M	16	1/16	8	2.8	85	ECO 7255	16	16
2:								
Arriflex M	16	1/16	8	2.8,4, 5.6,8	85	ECO 7255	16	16
Veritron	65	1/50	1	--	--	EKTA MS 5256	65	70
3:								
Milliken	17.7	--	500	2.8	85	ECO 7255	16	16
4:								
Arriflex M	16	1/16	8	2.8,4, 5.6,8	85	ECO 7255	16	16
5:								
Arriflex M	16	1/16	8	2.8,4, 5.6	85	ECO 7255	16	16
Veritron	65	1/50	1	--	--	EKTA MS 5256	65	70
6:								
Nikon	55	1/125	1/[1/] 1/[2/] 1	4,5.6	--	Kodachrome II	25	35
7:								
Nikon	45	1/125	1/[1/] 1/[2/] 1	4,5.6	--	Kodachrome II	25	35
Nikon	112	1/60	1/[1/] 1/[2/] 1	2.8,4	--	Kodachrome II	25	35

[1/] Per 10 seconds.

[2/] Per 30 seconds.

Milliken: The accuracy of the frames per second is dependent on the battery power supply.

c. Data: Clocks were used to record time in all frames except camera station 3 and in the documentary cameras. Usable data are available from all cameras except the 70-mm Veritrons. As a result of battery problems only 200 feet of film at 500 frames per second were obtained from the Milliken high speed camera.

d. Volume of Data:

Camera Station	Original	Copy
1	1,100 ft.	1
2	1,100 ft.	1
3	300 ft.	1
4	1,100 ft.	1
5	1,100 ft.	1
6	400 slides	1
7	446 wide angle lens slide	1
	366 telephoto lens slide	1
Documentary	2,000 ft.	

6. Security Clearance: Unclassified.

7. Volume of Records: 40,117 pages of computer listings, 35 pages of tabulated sheets, one strip chart, six reels of film, and 1,300 slides, on file at the Forest Fire Laboratory, P. O. Box 5007, Riverside, California 92507.

8. Data Released: June 30, 1968.

9. Cooperator Studies:

a. Radiation, wind and evaporation, by United Kingdom Joint Fire Research Organization.

b. Fuel Evaluation, by Canadian Department of Forestry and Rural Development.

c. Infrared spectra, radiation temperature, television, low-light television and radar, by Boeing Company.

d. Indraft winds, by Dikewood Corporation

e. Noxious gases, by Engineering Department University of California at Los Angeles

f. Visibility in streets and infrared, by U. S. Naval Radiological Defense Laboratory.

g. Movement of solid particles and soil temperature, by Stanford Research Institute

h. Pibal, radiosonde, rawin studies, by Fire Meteorology Project, Pacific Southwest Forest and Range Experiment Station.

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13. ABSTRACT

Summarizes, in catalogue form, the data available from nine experimental fires conducted from 1964-1967 by Project Flambeau, a research activity of the Pacific Southwest Forest and Range Experiment Station. The fires were burned as part of an investigation of mass fire sponsored by the Office of Civil Defense, Department of the Army, and by the Defense Atomic Support Agency, Department of Defense. The types of data available, their form, and where they are on file are listed.

DD FORM 1 NOV 65 1473 REPLACES DD FORM 1473, 1 JAN 64, WHICH IS OBSOLETE FOR ARMY USE.

Security Classification

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fire behavior						
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thermal radiation						
airflow						
fuel moisture						
flame zone temperature						
heat flux						
convection columns						

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Key Words: fire storms; fire behavior; Flambeau (Project); fuel weight loss; thermal radiation; air flow; fuel moisture; flame zone temperature; heat flux; convection columns.

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